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BROADWATER

RESOURCE REPORT NO. 13

ENGINEERING AND DESIGN MATERIAL

MAIN REPORT

PROPOSED FLOATING STORAGE REGASIFICATION UNIT

FOR A

LIQUIFIED NATURAL GAS RECEIVING TERMINAL

IN

LONG ISLAND SOUND

LONG ISLAND, NEW YORK

UNITED STATES OF AMERICA

JANUARY 2006

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RESOURCE REPORT 13 - ENGINEERING AND DESIGN MATERIAL	
Minimum Filing Requirements	**Location in Environmental Report**
☐ Provide a detailed plot plan showing the location of all major components to be installed, including compression, pretreatment, liquefaction, storage, transfer piping, vaporization, truck loading/ unloading, vent stacks, pumps, and auxiliary or appurtenant service facilities. (18CFR § 380.12 (o) (1))	Section 13.1
☐ Provide a detailed layout of the fire protection system showing the location of fire water pumps, piping, hydrants, hose reels, dry chemical systems, high expansion foam systems, and auxiliary or appurtenant service facilities. (18CFR § 380.12 (o) (2))	Section 13.2
☐ Provide a layout of the hazard detection system showing the location of combustible-gas detectors, fire detectors, heat detectors, smoke or combustion product detectors, and low temperature detectors. Identify those detectors that activate automatic shutdowns and the equipment that would shut down. Include all safety provisions incorporated in the plant design, including automatic and manually activated emergency shutdown systems. (18CFR § 380.12 (o) (3))	Section 13.3
☐ Provide a detailed layout of the spill containment system showing the location of impoundments, sumps, subdikes, channels, and water removal systems. (18CFR § 380.12 (o) (4))	Section 13.4
☐ Provide manufacturer's specifications, drawings, and literature on the fail-safe shut-off valve for each loading area at a marine terminal (if applicable). (18CFR § 380.12 (o) (5))	Section 13.5
☐ Provide a detailed layout of the fuel gas system showing all taps with process components. (18CFR § 380.12 (o) (6))	Section 13.6

RESOURCE REPORT 13 - ENGINEERING AND DESIGN MATERIAL	
Minimum Filing Requirements	**Location in Environmental Report**
☐ Provide copies of company, engineering firm, or consultant studies of a conceptual nature that show the engineering planning or design approach to the construction of new facilities or plants. (18CFR § 380.12 (o) (7))	Section 13.7
☐ Provide engineering information on major process components related to the first six items above, which include (as applicable) function, capacity, type, manufacturer, drive system (horsepower, voltage), operating pressure, and temperature. (18CFR § 380.12 (o) (8))	Section 13.8
☐ Provide manuals and construction drawings for LNG storage tank(s). (18CFR § 380.12 (o) (9))	Section 13.9
☐ Provide up-to-date piping and instrumentation diagrams. Include a description of the instrumentation and control philosophy, type of instrumentation (pneumatic, electronic), use of computer technology, and control room display and operation. Also, provide an overall schematic diagram of the entire process flow system, including maps, materials, and energy balances. (18CFR § 380.12 (o) (10))	Section 13.10
☐ Provide engineering information on the plant's electrical power generation system, distribution system, emergency power system, uninterruptible power system, and battery backup system. (18CFR § 380.12 (o) (11))	Section 13.11
☐ Identify of all codes and standards under which the plant (and marine terminal, if applicable) will be designed, and any special considerations or safety provisions that were applied to the design of plant components. (18CFR § 380.12 (o) (12))	Section 13.12

RESOURCE REPORT 13 - ENGINEERING AND DESIGN MATERIAL	
Minimum Filing Requirements	**Location in Environmental Report**
☐ Provide a list of all permits or approvals from local, state, Federal, or Native American groups or Indian agencies required prior to and during construction of the plant, and the status of each, including the date filed, the date issued, and any known obstacles to approval. Include a description of data records required for submission to such agencies and transcripts of any public hearings by such agencies. Also provide copies of any correspondence relating to the actions by all, or any, of these agencies regarding all required approvals. (18CFR § 380.12 (o) (13))	Section 13.13
☐ Identify how each applicable requirement will comply with 49 CFR part 193 and the National Fire Protection Association 59A LNG Standards. For new facilities, the siting requirements of 49 CFR part 193, subpart B, must be given special attention. If applicable, vapor dispersion calculations from LNG spills over water should also be presented to ensure compliance with the U.S. Coast Guard's LNG regulations in 33 CFR part 127. (18CFR § 380.12 (o) (14))	Section 13.14
☐ Provide seismic information specified in Data Requirements for the Seismic Review of LNG facilities (NBSIR 84–2833, available from FERC staff) for facilities that would be located in zone 2, 3, or 4 of the Uniform Building Code Seismic Map of the United States. (18CFR § 380.12 (o) (15))	Section 13.15

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
1. Resource Report 13 should clearly indicate that the floating storage and regasification unit (FSRU) would be considered an offshore structure rather than a vessel.	Main Report - Introduction
2. Please note that a third party/classification society should review and concur with the use of any Rule, Code, or Standard prior to implementation into the proposed design and prior to any further design submittals to the FERC.	Main Report - Section 13.1.1
3. Section 13.9.1.2 appears to indicate that Broadwater would maintain class over the life of the facility. Please note that if Broadwater elects to drop class at any time, the maintenance and inspection philosophies must address a third party regime for ensuring compliance with the design basis assumption and the material condition required by all applicable standards over the life of the facility. If the third party option is exercised, the Coast Guard, in conjunction with FERC, would have to approve selection of the third party based upon the qualifications stated in the DWP NVIC 03-05.	Main Report - Section 13.1.1
4. Any symbol, code, or marking used on drawings and diagrams should be identified in a legend or key. Drawings depicting position information should also be referenced to a master drawing indicating the location of the area covered. In addition, each drawing/plan should clearly indicate the specific deck represented.	Throughout appendices

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
5. Provide a description of the process undertaken to decide which Rule, Code, or Standard is the more stringent requirement as stated in section 13.1.1 of Resource Report 13. In general, the following questions should be addressed: a. Who determines whether or not the standard is applicable to the system and whether or not the standard is compatible with other standards being applied to the same system or set of integrated systems? b. Who decides which standard is the most stringent? c. What is and/or has been the role of a third party/classification society in this decision or process?	Main Report Section 13.1.1
6. Broadwater should provide detailed drawings showing a more complete view of sections on the FSRU. Note that an overall drawing of the entire facility in 11" x 17" format cannot provide the necessary clarity needed for review. Larger scale general arrangements and/or unit drawings should be on a separate 11" x 17" page to clearly show the mooring arrangement with the LNG vessel, the cargo unloading platform, and major utility systems.	Throughout appendices
7. The facility design must provide 200% lifeboat capacity. Consider the use of a free-fall launched lifeboat at the forward temporary refuge, as well as limited application of liferafts from the weather deck. In addition, address other personal lifesaving equipment and gear such as immersion suits. Lifeboats must comply with section 4.9 of the IMO International Lifesaving Appliance Code.	Main Report Section 13.1.2.5
8. Describe all circumstances which would result in the removal of the FSRU crew. In addition, identify the maximum design weather conditions for which LNG loading operations, as well as production operations, would cease.	Main Report Section 13.1.2.5

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
9. Provide a description of the "marine activities" referenced on page 13-12 of Resource Report 13, section 13.1.2.8.	Main Report Section 13.1.2.8
10. Broadwater should submit a tabulated list of all hazard control equipment, both fixed and portable, that includes the following information for each individual piece of equipment: location and/or area to be covered; type of system; size; tag number; and automatic activation capabilities.	Appendix 13.2.1
11. The design and installation of electrical equipment, as well as the designation of hazardous locations, should comply with the National Electric Code rather than the International Electric Conventions, as stated in part 6.2 of the "Fire & Explosion Strategy" located in appendix 13.2.1 of Resource Report 13.	Main Report Section 13.11.1
12. Provide a copy of the IP-15 specification referenced in part 6.2 of the "Fire & Explosion Strategy" located in appendix 13.2.1 of Resource Report 13.	To be issued under separate cover.
13. Specifically address fire protection for the FSRU in the event of an on-water pool fire to include, but not be limited to, a pool fire between the FSRU and the LNG carrier. Would the installed systems provide adequate protection to disconnect loading arms / cast off mooring lines in the event of a fire while an LNG carrier is moored?	Main Report Section 13.2.2.11
14. Provide general arrangement and profile drawings that detail the structural fire protection boundaries of each space.	Main Report Section 13.2.2. & Appendix 13.2.1
15. Specify the fire-fighting capabilities of the assist tugs which would dedicated to FSRU operations.	Main Report Section 13.2.2.10

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
16. Broadwater should submit detailed drawings of the hazard detection system. Note that an overall drawing of the entire hazard detection system in 11" x 17" format cannot provide the necessary clarity needed for review. Larger scale arrangements and/or unit drawings should be on a separate 11" x 17" page to clearly show the hazard detection system.	Appendix 13.3
17. Broadwater should submit a tabulated list of all hazard detection equipment, including: location and equipment or area monitored; type; tag number; activation points for alarm and shutdown including dual actuation or voting systems; and automatic activation of hazard control equipment such as dry chemical or high expansion foam systems and delay settings.	Appendix 13.3
18. Describe the provisions, if any, to transmit hazard detection and other information to the shore-side support facilities.	Main Report Section 13.3.8
19. Provide a description of the equipment or procedures which would be used to provide redundant leak/spill detection in the voids between the inner and outer hulls, as well as in the cofferdams.	Main Report Section 13.3.9
20. Broadwater should provide drawings showing potential LNG spill locations and how all spills would be directed off the FSRU. The drawings should depict all troughs and spillways necessary to direct/control potential spills and should indicate to which side of the FSRU the spills would be directed.	Appendix 13.4

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
21. In addition to the calculations included in section 13.4, provide thermal radiation and vapor dispersion calculations for spills based on the cargo tank breaches for both accidental and intentional events specified in the Sandia Report. This analysis should include: a. a specific comparative analysis demonstrating that the proposed FSRU, and any LNG carriers to be used, would be analogous to the vessels studied in the Sandia Report; b. the meteorological data (including the source) supporting the wind speed, atmospheric temperature, and humidity used in all hazard analyses; c. calculations and validation of the vapor cloud source term used in the downwind dispersion modeling resulting from an LNG pool on water; and` d. an assessment of any differences in the results of Broadwater's site-specific modeling and the generic results/hazard zones described in the Sandia Report. As stated in the September 30, 2005 letter, the items above should be included as public information in Resource Report 11. Supporting information (modeling runs, calculations, drawings, etc.) should be put in an appendix to Resource Report 11 and, if necessary, may be labeled as CEII.	Main Report Section 13.4.7
22. Clarify the source or location of the spill considered in section 13.4.6. Is this a break at the manifold which would drain to the starboard side or is it in the vicinity of the cargo dome which would drain to the port side?	Main Report Section 13.4.6
23. Describe the measures which would be used to prevent all LNG spills from affecting the yoke mooring tower and the FSRU hull.	Main Report Section 13.4.4

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	Location in Environmental Report
24. Broadwater should provide manufacturer's specifications, drawings, and literature on the fail safe shut off valve for each loading area. Information should include means of actuating shut off valves whether manual, fire, ESD, or loss of power or air and the basis for valve closure time.	Appendix 13.5
25. Broadwater should provide the basis of design used to develop the front end engineering design (FEED). The result of all hazard design reviews used to develop the FEED should be included.	Main Report Section 13.7 and Appendix 13.7
26. Broadwater should provide studies that support a design decision such as selecting a specific type of equipment where other alternatives were available. For example, studies supporting the choice of twin 30 inch transfer lines versus one 42 inch; full containment versus single containment, and so on.	Main Report Section 13.7 and Appendix 13.7
27. Since the FSRU would be considered an offshore structure, regulations for the discharge of sewage from vessels are not applicable and a system meeting IMO requirements, as discussed in section 13.8.2.10 of Resource Report 13, would not be acceptable. Describe the regulations/standards which would apply to the discharge of treated sewage from the FSRU.	Main Report Section 13.8.2.10
28. Describe the regulations/standards which would apply to the discharge of bilge water from the FSRU.	Main Report Section 13.8.2.13
29. Address how corrosion prevention measures would be monitored and any impacts to the maintenance and inspection philosophies. Describe any potential environmental concerns that may be associated with any proposed corrosion prevention measures.	FSRU Hull and Containment Appendix 13.9.14

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
30. Broadwater should discuss in significant detail the sloshing analysis discussed in Section 13.9.27. This section should address the following: a. The research, development, and validation of the ABS SafeHull LNG formulas used to calculate the natural frequency of each cargo tank. b. The specific measures to be taken to maintain the cargo tank natural frequency outside the range of the FSRU's excitation period. c. The use and validation of the "SHI-SLOSH" program for analyzing sloshing loads. d. Confirmation that the maximum motion response is being applied at the tank's natural frequency so as to ensure the evaluation of worst-case sloshing loads.	FSRU Hull and Containment Appendix 13.9.27
31. The FSRU's response to metocean conditions are discussed in numerous sections of Resource Report 13. Each section which addresses the application of metocean conditions to a design element or system should specify whether or not the metocean conditions are combined wave-current-wind conditions. Alternatively, these sections should reference a specific metocean condition(s) or FSRU response analysis considered in the design.	Main Report Section 13.1.2.5
32. Broadwater should provide revised piping and instrumentation diagrams which include: completed tagging for all valves and instrumentation; pressure-relief set points; and a depiction of the control loops. In addition, all symbols and line types used should be identified in the legend.	Appendix 13.10.1 P&IDs

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	Location in Environmental Report
33. Broadwater should provide complete process flow diagrams where all stream tags are consistent with the process flow data given. For example, drawing 312383-SAI-PFD-101.dwg lists an S14 stream in the properties table but no S14 stream is shown on the process flow diagram.	Appendix 13.8.1 Process Flow Diagrams
34. Project-specific pipe specifications, rather than piping code references, should be provided for each individual piping material which would be used on the project. These specifications should be keyed to the line designations and should, at a minimum, indicate: the piping material; the pressure and temperature design conditions; and the type of joints, gaskets, and valves to be used for each application.	Appendix 13.10.1
35. Provide a tabulated list of the codes and/or standards which would be applicable to the design and construction of the yoke mooring system. Identify each component and the specific code/standard including section reference which would be used.	Appendix 13.16 Yoke Mooring System
36. Discuss the training and qualification requirements for FSRU personnel involved in the following operations: LNG cargo transfers from the LNG carrier to the FSRU internal transfers onboard the FSRU and regasification operations with particular emphasis on differences if any between the training and qualification requirements for personnel conducting similar operations at an on shore facility. Training and qualification requirements for personnel engaged in marine operations was previously discussed in your letter to the Coast Guard Captain of the Port Long Island Sound dated November 1 2005.	Main Report Section 13.14 (ref RR11)
37. Provide a description of the geotechnical investigations undertaken in the design of the mooring tower.	Appendix 13.16 YMS Design Basis

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
38. Discuss the existence of, or consideration given to, alternative/back-up mooring arrangements that may be used in the event of a yoke mooring system (YMS) failure. Please note that any decision on whether to accept the mooring systems design criteria without back-up/secondary mooring systems (as proposed) is dependent upon the Coast Guard's waterway safety assessment and the results the Coast Guard/Minerals Management Service's review of mooring failures/facility damage in the Gulf of Mexico following recent storm activities.	Main Report Section 13.16.2
39. Provide additional details regarding the specific loading conditions evaluated for the YMS with and without a LNG carrier moored alongside the FSRU. These loadings should also consider the damage criteria required by the IGC.	Main Report Section 13.16
40. Provide additional details regarding the structural performance of the YMS, specifically the range and type of motions allowed by all linkages. Ranges should consider the loading conditions addressed above.	Appendix 13.16 Yoke Mooring System
41. Specify the experience of the company which would be designing the YMS.	Main Report Section 13.16.2
42. Provide detailed cut sheets or drawings of the slewing bearing, mooring head, and other bearings critical to the soft yoke mooring system.	Appendix 13.16 Yoke Mooring System
43. Provide a copy of the basis of design document used for the "Yoke Mooring System Design Report" located in appendix 13.6.	Appendix 13.16 YMS Design Basis

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
44. Liferafts with sufficient capacity to hold the maximum number of personnel expected on the platform at any given time, considering heavy maintenance and repairs, should be included in the tower design.	Appendix 13.16 Yoke Mooring System
45. Provide a copy of the Noble Denton guidelines used for transport motions as referenced on page 4 of the "Yoke Mooring System Design Report" located in appendix 13.6.	Appendix 13.16
46. Page 6 of the "Yoke Mooring System Design Report" in appendix 13.6 states that the fatigue life of the proposed facility is evaluated at 30-years. Please note that additional fatigue studies and detailed inspections would be required if Broadwater requests, at any time, to operate the facility for more than 30 years.	Noted.
47. Page 15 of the "Yoke Mooring System Design Report" located in appendix 13.6 states that the driving system would be designed to a Lloyd's Register rule. Confirm that the contracted classification society (American Bureau of Shipping) would review and class the driving system to this standard.	Appendix 13.16 Yoke Mooring System
48. Explain why dynamic loadings were not considered for the mooring support structure, the yoke, and the turntable and manifold deck.	Main Report Section 13.16.2
49. Provide the metocean report referenced in paragraph 3.2 of the "Broadwater FSRU Preliminary Hydrodynamic Load Report" in section 13.16. If not included in the report, Broadwater should provide details regarding source data and acceptance of metocean conditions by a third party or classification society.	Appendix 13.16 YMS Design Basis

ENVIRONMENTAL INFORMATION REQUEST DATED NOVEMBER 23, 2005	
Request	**Location in Environmental Report**
50. Provide the following information regarding the manual release at the quick release hook (QRH): a. the time required to release all mooring lines; b. personnel actions required to release all lines; c. a list of recommended practices by the ship-to-ship transfer guides; and d. an assessment of alternative systems, including remote automatic activation, to a manual release at the QRH.	Appendix 13.17 Mooring and LNG loading facilities
51. Broadwater should explain the assumption of a maximum simultaneous roll of three degrees for the FSRU and LNG carrier.	Appendix 13.17 Mooring and LNG loading facilities
52. Specify the repair/replacement procedures for the fendering system for the entire range of LNG carriers which would be received at the facility. Could a fender be replaced if damaged while a LNG carrier is alongside? If not, what would be the minimum number of fenders required for safe operation? A philosophy of N+1 does not seem to be incorporated in the proposed design, unless the repair/replacement procedure would require stopping transfer operations and movement of the LNG carrier to effect repairs.	Appendix 13.17 Mooring and LNG loading facilities

Table of Contents

List of Acronyms and Abbreviations

Acronyms and Abbreviations	Definitions
ABS	American Bureau of Shipping
AC	Alternate Current
AES	Advanced Encryption Standard
AFBMA	Anti Friction Bearing Manufacturer's Association
AFFF	Agent Forming Floating Foam
API	American Petroleum Institute
AHU	Air Handling Unit
ALARP	As Low As Reasonably Practicable
ANSI	American National Standards Institute
APT	Aft Peak Tank
ARPA	Automatic Radar Plotting Aide
ASME	American Society Of Mechanical Engineers
ASTM	Aastrom Biosciences
ATM	Atmospheric Pressure
AWS	American Welding Society
BDV	Blow Down Valve
BL	Battery Limits
BoD	Basis of Design
BOG	Boil-Off Gas
Btu	British Thermal Units
Buyer, the	FSRU Owner
BV	Bureau Veritas
CAA	Civil Aviation Authority
CCR	Central Control Room
CCTV	Closed Circuit Television
CER	Central Equipment Room
CFR	(US) Code of Federal Regulations
Class, the	Classification Society

Acronyms and Abbreviations	Definitions
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CoG	Center of Gravity
CTS	Custody Transfer System
DC	Direct Current
DCS	Distributed Control System
DEP	Design and Engineering Practice
DGPS	Differential Global Positioning System
DIN	Deutsches Institut fur Normung
DLA	Dynamic Load Analysis
DLE	Dry Low Emission
DNV	Det Norske Veritas
DO	Diesel Oil
DP	Dynamic Positioning
DSS	Digital Spread Spectrum
ECR	Engine Control Room
EDG	Emergency Diesel Generator
EER	Escape Evacuation And Rescue
EMD	Electric Motor-Driven
EMI	Electromagnetic Interference
ESD	Emergency Shut Down
F & G	Fire And Gas
FCC	Federal Communication Commission
FEA	Fire And Explosion Assessment/Finite Element Analysis
FES	Fire And Explosion Strategy
FGS	Fire and Gas System
FPT	Forward Peak Tank
FRP	Fiber Reinforced Plastic

FSRU	Floating Storage Regasification Unit
FSWR	Flexible Steel Wire Rope
GTT	Gaz Transport Et Technigaz
GRP	Glass Fiber Reinforced Plastic
HAZID	Hazard Identification (Review)
HM	Heating Medium
HMPE	High Modulus Poly Ethylene
HIPPS	High Integrity Pressure Protection System
HP	High Pressure
HPU	Hydraulic Power Unit
H/V	High Voltage
HVAC	Heating Ventilation and Air Conditioning
IACS	International Associations of Classification Societies
IALA	International Association of Lighthouse Authorities
IBS	Interbarrier Space
ICCP	Impressed Current Cathodic Protection
ICS	Incident Command System Or International Chamber Of Shipping
IEC	International Electric Conventions
IG	Inert Gas
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (Gas Carrier Code)
IGG	Inert Gas Generator
ILO	International Labor Organization
IMO	International Maritime Organization
I/O	Input/Output
IP	Internet Protocol
IPF	Instrumented Protection Functions
IPS	Instrumented Protective Fire; Instrument Protection System
IR	Infrared
IS	Intrinsically Safe; Insulation Space

ISGOTT	International Safety Guide For Oil Tankers And Terminals
ISO	International Standards Organization
ITU	International Telecommunication Code
JIS	Japan Industrial Standard
KO	Knockout
KW	Kilowatt
LAER	Lowest Achievable Emission Reduction
LAN	Local Area Network
LCs	Large Corrugations
LFL	Lower Flammable Limit
LMP	Loading Monitoring Program
LNG	Liquefied Natural Gas
LP	Low Pressure
LR	Lloyds Register
LSA Code	Life-Saving Appliances Code
LSD	Loading Shutdown Switches
L/V	Low Voltage
MARPOL	International Convention For The Prevention Of Pollution From Ships
MARVS	Maximum Allowable Relief Valve Setting
Mbps	Megabytes per second
MDO	Marine Diesel Oil
MF	Medium Frequency
MGPS	Marine Growth Prevention System
mmscfd	Million Standard Cubic Feet /Day
MODU	Mobile Offshore Drilling Unit
MSS	Mooring Support Structure
M/V	Medium Voltage
MW	Megawatt
NDT	Non Destructive Test

NEMA	National Electrical Manufacturer's Standard
NFPA	National Fire Protection Association
NG	Natural Gas
NO_x	Nitrogen Oxide/Oxides of Nitrogen
OCIMF	Oil Companies International Marine Forum
PA	Public Address
PABX	Private Automatic Branch Exchange
PCHE	Printed Circuit Heat Exchanger
PCS	Process Control System
PDH	Plesiochronous digital hierarchy
PERC	Powered Assisted Emergency Release Coupling
PFD	Process Flow Diagram
PIR	Polyisocyanurate
PSFS	Process Safeguarding Flow Scheme
psig	Pounds per square inch gauge
PSV	Process/Pressure Safety Valve
PTL	Project Technical Liaison Associates Inc.
PVC	Polyvinyl Chloride
QC/DC	Quick Connect/Disconnect Coupler
QRH	Quick Release Hook
RO	Reverse Osmosis
RPT	Rapid Phase Transition
RR13	Resource Report Section 13
SBMI	SBM IMODOCO
SCs	Small Corrugations
SCR	Selective Catalytic Reduction
SDV	Shut Down Valve
SFA	Spectral Fatigue Analysis
SI	Integrated System of Units
SIS	Safety Instrumentation system
SIGTTO	Society of International Gas Tanker and Terminal Operators

SNAME	Society of Naval Architects and Marine Engineers
SNMP	Simple Network Management Protocol
SOLAS	Safety of Life at Sea
SPM	Single Point Mooring
SSIV	Sub Sea Isolation Valve
STV	Shell and Tube Vaporizer
SUS	Stainless Steel
Shell	Shell Broadwater Holdings LLC
SWBM	Still Water Bending Moment
SWA	Safe welding area
SWL	Safe Working Load
TA	Technical Advisor
TMCP	Thermo Mechanical Controlled Process
TCPL	TCPL USA LNG Ltd.
TEMA	Tubular Exchangers Manufacturers Association
TIG	Tungsten Inert Gas
TR	Temporary Refuge
TSCF	Tanker Structures Cooperative Forum
UPS	Uninterruptible Power Source
USCG	United States Coast Guard
UV	Ultraviolet
WC	Water Column or Water Closet
WHRU	Waste Heat Recovery Unit
WMS	Weather Monitoring System
YMS	Yoke Mooring System

Glossary of Marine Terms

This glossary provides a list of the definitions of some of the nautical terms used in the report, the majority of which have been used to prevent ambiguity in the context of establishing the relative position of the FSRU or location of equipment on the FSRU. This list does not cover terms used in any specialist detailed Naval Architecture content.

Marine Term	Definition
Abaft	Toward the rear (stern) of the FSRU.
Abeam	At right angles to the FSRU as per an LNG carrier coming alongside.
Aboard	On or within the FSRU.
Abreast	Side by side.
Aft	Toward the rear (stern) of the FSRU (the opposite end to the yoke mooring).
Aft Peak	Ballast tanks used at the aft end of the FSRU.
Ahead	In a forward direction.
Amidships	In or toward the center of the FSRU.
Astern	In the rear of the FSRU, opposite of ahead.
Athwartships	At right angles to the centerline of the FSRU.
Ballast Tanks	Compartments (tanks) used for the storage of water ballast.
Beam	The greatest width of the FSRU.
Below	Beneath the main deck.
Bow	Structural arrangement/form of the FSRU forward end that is attached to the yoke mooring system.
Bridge	The location on the LNG carrier from which it is controlled when under way.
Bulkhead	A structural partition, usually vertical, sub dividing the interior of the FSRU into compartments.
Buyer, the	FSRU Owner
Camber	The upward rise of a deck from both sides towards the centerline of the FSRU.
Coaming	The vertical boundary structure surrounding an area for containment purposes.
Cofferdams	The spaces between two bulkheads primarily designed as a safeguard against leakage between one compartment and another.
Draught	The depth of water the FSRU draws.
Forepeak	A ballast compartment in the bow of the FSRU.
Forward	Towards the bow of the FSRU.
Freeboard	The vertical distance from the surface of the water to the main deck of the FSRU.
Heading	The direction in which the FSRU's bow points while weathervaning.

Marine Term	Definition
Hull	The main body of the FSRU in which the containment system (storage) is located.
Inboard	More towards the center of the FSRU.
Inner Trunk Deck	Hull deck covering the LNG storage tanks.
Jumper	Flexible flow line.
Leeward	The direction away from the wind; opposite of windward.
Main Deck	Hull lower deck.
Midship	Approximately in the location equally distant from the bow and stern.
Outboard	Toward or beyond the FSRU's sides.
Port	The left side of the FSRU looking forward.
Scantlings	The physical dimensions of a structural item.
Starboard	The right side of the FSRU when looking forward towards the yoke mooring system. LNG carriers will moor on the starboard side of the FSRU.
Stern	The after part of the FSRU.
Thwartships	At right angles to the centerline of the FSRU.
Topsides	In nautical terms it is the sides of a vessel between the waterline and the main deck or sometimes referring to onto or above the deck. On the FSRU, it is this latter interpretation but is used liberally as the process equipment above the trunk deck.
Transom	The stern cross-section of the FSRU.
Trim	Fore and aft level of the FSRU.
Trunk Deck	Hull upper deck.
Windward	Toward the direction from which the wind is coming.

SI Units Conversion Table

Parameter	SI Unit	Conversion Factor	Imperial Unit
Force	kN	= 0.223	kips
Gas volume	Nm3	= 33.284	scf (standard cubic foot)
Power	kW	= 1.341	HP (horsepower)
Pressure	bar	= 14.50	psi (pounds per square inch)
Pressure	kPa	= 0.145	psi
Thermal radiation	kW/m^2	= 315	Btu (British Thermal Units)/hr/ft^2
Weight	t (for metric ton)	= 2204.6	lb (pounds)

13. ENGINEERING AND DESIGN MATERIAL

Introduction

Broadwater Energy, a joint venture between TCPL USA LNG Inc. and Shell Broadwater Holdings LLC, is filing an application with the Federal Energy Regulatory Commission (FERC) seeking all of the necessary authorizations pursuant to the Natural Gas Act to construct and operate a marine liquefied natural gas (LNG) terminal and interconnected subsea pipeline for the importation, storage, regasification, and transportation of natural gas. The Broadwater LNG Project (the Project) will increase the availability of natural gas to the New York and Connecticut markets through an interconnection with the Iroquois Gas Transmission System (IGTS).

Site Plan

The proposed Broadwater LNG import terminal will be located in Long Island Sound, approximately 14.5 km (9 miles) off the coast of Riverhead, New York, and approximately 18 km (11 miles) from the nearest Connecticut shoreline, in a water depth of about 28 m (90 feet).

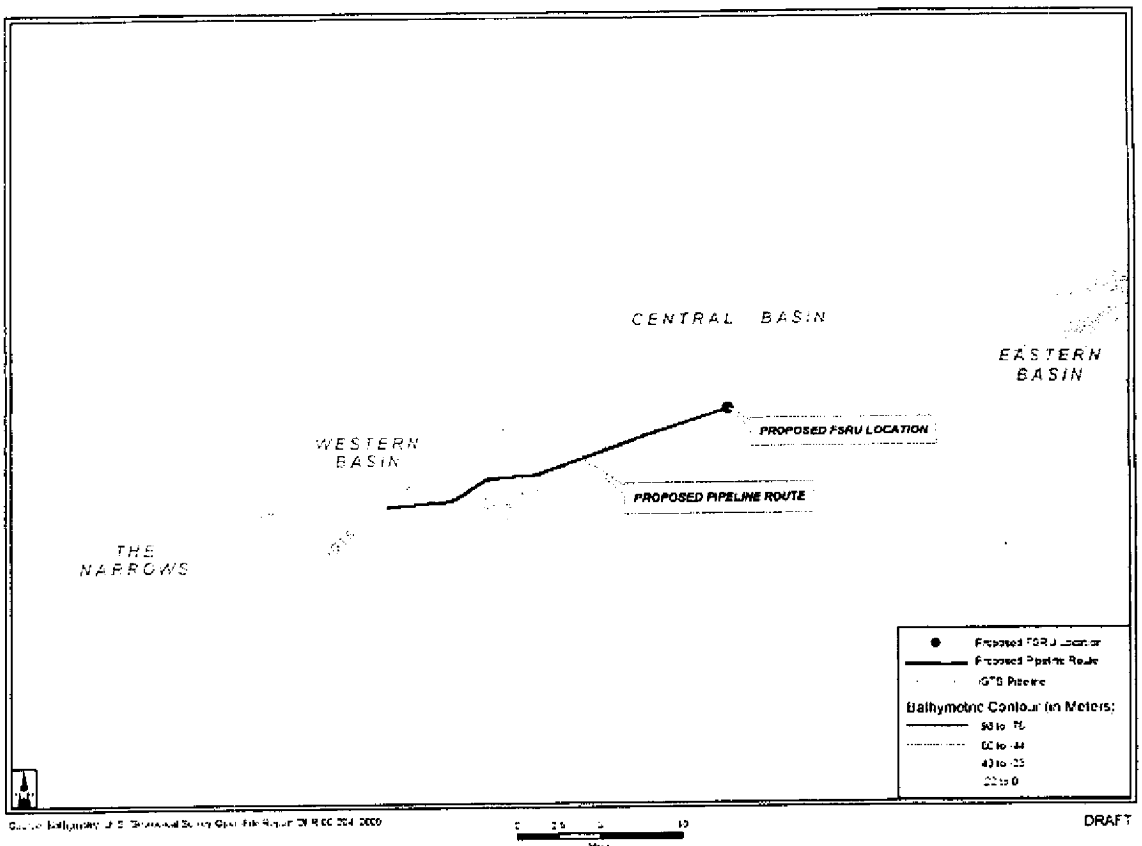

Figure 0-1: Location of the Proposed Terminal Site within Long Island Sound

is provided at the aft end of the FSRU to assist, if required, during berthing operations of the LNG carriers.

At midship on the FSRU, there are four conventional 16" loading arms: two arms for the LNG transfer at a rate of 10,000 m^3/h, one vapor return arm, and one spare vapor/liquid arm. The arms are equipped with a guiding assistance system to ensure proper alignment for mating the arm connector onto the LNG carrier manifold flange, thus providing a quick and reliable connection despite the relative motions between the two hulls.

The mooring lines are attached to quick release hooks (QRH) and the arms are equipped with quick connect/disconnect couplers (QC/DC). These features facilitate a quick unberthing/ disconnection in case of emergency.

2. LNG Storage Tanks

The LNG net storage capacity of the FSRU is 350,000 m^3. The cargo area is split into eight membrane-type LNG storage tanks. A water ballast system is used to control the FSRU draft during regasification and loading operations. The water ballast system is also used for adjustment of the facilities' trim, heel, stability and bending moment and adjustment of the facility due to shear force. The ballast tanks are segregated and are comprised of two ballast peak tanks (one aft, one fore) and nine pairs of wing and double bottom ballast tanks adjacent to the cargo area.

The steel structure of the cargo hold is designed to have double skin arrangement for the bottom, sides, and trunk deck. The cargo structure and LNG containment systems are strengthened in order to withstand all partial filling conditions. Passageways are provided under the trunk deck, and both the port and starboard sides to house utilities piping, fire water piping, and most of the electrical and instrumentation cables.

3. Regasification Plant

The Regasification Plant is designed to vaporize LNG at a peak capacity of about 2,500 cubic meters per hour (m^3/hr) (corresponding to 1,250 million standard cubic feet per day [mmscfd] of NG). Each cargo tank has a removable submerged in-tank pump. LNG is pumped from the LNG storage tanks to the recondenser, which operates at about 8 barg. This recondenser is designed to condense all of the boil-off gas (BOG) from the tanks including the additional BOG generated during loading operations and the injected nitrogen (*See* Section 5). The four BOG compressors can accommodate the varying BOG rates by using a recycle line and by starting/stopping compressors as required.

There are eight high pressure (HP) send-out pumps, each one feeding one vaporizer. The HP pumps are of vertical submerged motor multistage centrifugal type. The discharge pressure can be up to 106 barg. The eight vaporizers are of the Shell and Tube Vaporizer (STV) type. The heating medium is a glycol water mixture supplied at a temperature between 72°C and 85°C. From the vaporizers, the send-out gas goes to the superheaters (printed circuit type exchangers). The superheating system is designed to heat gas from 20°C to as much as 62°C at peak send-out rate. The superheaters use the higher temperature of the heating medium stream coming from the Waste Heat Recovery Units (WHRU) installed on the gas turbines. The gas is then metered and odorized, which demarcates the beginning of the send-out pipeline system. A flare stack is provided to safely dispose of any hydrocarbon release. The flare only ignites in the event of an emergency upset to the facility.

All the process facilities are located on a process deck at the forward area of the FSRU as far from the accommodation area as possible.

4. Natural Gas Send-out

The transfer of the NG send-out gas between the FSRU and the pipeline is achieved through a series of jumpers that are suspended between the Mooring Support Structure (MSS) on the FSRU and the turntable structure on the fixed mooring tower.

The tower provides the integrated mooring base for the FSRU and the structural support for the send-out pipeline. The gas flows through HP swivel joints and continues down to the subsea portion of the pipeline system through the riser and a submerged subsea safety valve.

The FSRU is moored by means of a soft yoke mooring system (YMS) to a fixed jacket, which is piled to the seabed. The jacket is a tubular steel structure of square horizontal cross-section with legs in each of its four corners. A central column or 'king post' is located at the top of the jacket onto which the turntable is mounted. The turntable structure houses the swivel stack and is connected by means of a slewing bearing to the top of the king post. This allows the FSRU and the LNG carrier, if moored alongside, to weathervane around the piled jacket.

The mooring yoke consists of a rigid triangular tubular structure that is connected at the jacket end by a roll and pitch articulation to the turntable, and at the FSRU end by two mooring legs to the MSS mounted on the FSRU's bow.

5. Nitrogen Plant

Up to 4% of the regasified LNG that will be transported to markets may be nitrogen. Nitrogen can be injected into this gas to reduce its heating value and to meet the heating value and flame stability (Wobbe Index) requirements of downstream markets. Nitrogen injection is necessary due to the expected composition range of the LNG arriving at the terminal. The nitrogen generation unit is based on membrane technology and can produce 95.5% pure nitrogen. The gaseous nitrogen is injected upstream of the recondenser.

6. Power and Heat Generation

Main electric power is generated by three aero-derivative gas turbine generators: two running, one spare. The total installed capacity is about 70 megawatts (MW) (at the maximum ambient temperature). The units are located at trunk deck level, aft of the storage area and above the process heater room. One of the gas turbines will be dual fuel, which can operate on NG and on diesel oil (DO) to provide black start capability for the power plant. Exhaust gas from each gas turbine is sent to a combination WHRU and Selective Catalytic Reduction (SCR) unit mounted horizontally. The WHRU sections are used for supplemental heating of the glycol water loop. The SCR unit sections remove most of the carbon monoxide (CO) and nitrogen oxide (NO_x) before it is discharged to the atmosphere through a stack.

Essential and emergency power generation is achieved using three identical 2.4 MW diesel engine generators located in the accommodation area.

Main heat generation for the LNG vaporization is achieved by using up to four of the five process heaters located inside the hull below the gas turbine units. Exhaust gas from the heaters is directed to five vertical SCR units for removal of CO and NO_x before discharge to the atmosphere. Aqueous ammonia is atomized and injected in all the SCR units.

The heating medium system is a glycol water closed circulation loop that meets all the heating and cooling requirements of the FSRU without any need for pumping/discharging seawater during normal operating conditions. The heating medium provides heat to the vaporizers and the superheaters, but also to a heating water system (freshwater loop) that serves the other FSRU heating needs such as cofferdam heating and fuel gas heating. The glycol water loop also extracts heat from the cooling water system through a cross exchanger. The cooling water system is used for the cooling needs of the nitrogen compressors, the gas turbines, the machinery spaces, and the heating, ventilation, and air conditioning (HVAC). Seawater can be used as a back-up cooling medium in case the heating medium system is not in operation.

7. Accommodation Area

The accommodation area is located at the stern of the FSRU. It is sized for a permanent crew of up to 30 people (30 single cabins) plus a temporary crew of 30 people (15 double cabins). The accommodation area also houses public spaces, offices, the central control room (CCR), the telecom room, electric machinery rooms, workshops, and stores.

A helideck is located above the accommodation area in the optimum position for helicopter operability. In addition, a free-fall life boat is located at the stern, and an additional life boat is located forward.

13.1. SITING

13.1.1 Design Rules and Regulations Summary

The FSRU proposed by Broadwater for an LNG import terminal in Long Island Sound, New York, is not a typical "on-shore" LNG import terminal. (*See* Resource Report 1 for a more detailed description.) Located permanently offshore and attached to a YMS in a depth of 28 m, the FSRU is part LNG carrier, and part process plant.

The requirements set forth in 49 Code of Federal Regulations (CFR) Part 193 and the National Fire Protection Association (NFPA) 59A apply to an on-shore facility. Because this facility is floating offshore, many of the standards are not directly applicable. Accordingly, Broadwater has taken a proactive approach to the use of key requirements to ensure that the appropriate design, construction and operational codes, regulations, and standards are met with respect to the FSRU.

On-shore regulations and requirements are met with respect to certain portions of the process area. Ship regulations and requirements are applied to the "ship" part of the facility. As discussed in greater detail below in Section 13.14, the LNG processing facility will incorporate the purpose and the intent of the safety requirements detailed in 49 CFR Part 193 and NFPA 59A, even though not directly applicable, and will comply with all directly applicable regulations and codes.

The standards that govern the design and installation of the soft YMS are promulgated by the offshore classification societies (the Class) and the United States Coast Guard (USCG).

With respect to standards applicable to LNG carriers, the FSRU is designed and built in accordance with the provisions contained in the Class Rules for:

- The Classification of a Floating Offshore Installation at a Fixed Location;
- The Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk (which incorporates the International Gas Carrier Code [IGC]);
- Rules and Regulations for the Classification of Ships; and
- USCG Regulations.

Broadwater's evaluation of the applicable rules is included in each section of this Resource Report and separately in section 13.12 and 13.14 of this Resource Report. The Floating Offshore Installation rules are paramount. When more than one rule or standard applies Broadwater's policy is to apply the more stringent requirement. The Classification Society ABS has concurred with Broadwater's application of regulations, codes and standards.

These design codes and standards are further discussed in this section, as well as in Section 13.12, Design Codes and Standards.

A Classification Society will be engaged to ensure compliance with all of the Codes and Standards during the design and construction of the facility. In operation, Class need not be maintained, however a third party regime will be engaged (which may be a Classification

Society) that will be approved by the USCG in conjunction with FERC in compliance with DWP NVIC 03-05. The third party regime will ensure and verify compliance with the design basis assumption and the material condition required by all applicable standards over the life of the facility.

13.1.2 Factors Considered

Factors considered during site selection and design, as listed in 49 C.F.R. Part 193 Subpart B and NFPA 59A, include: (1) Thermal Radiation Protection; (2) Flammable Vapor Gas Dispersion Protection; (3) Soil Characteristics and Seismic Investigation; (4) Separation of Facilities; (5) Escape, Evacuation and Rescue (EER) Systems; (6) Temporary Refuge (TR), Muster Area and Shelters; (7) Soft Yoke Mooring; and (8) Adjacent Activities.

13.1.2.1 Thermal Radiation Protection

Federal regulations 49 CFR 193.2057 and NFPA 59A Section 2-2.3.1 require that the thermal radiation flux from an LNG fire meet stated limits: (1) for a design spill, and (2) for a fire over a tank impoundment area.

Design Spill

A design spill is defined in NFPA 59A (2001 version) Section 2-2.3.3(b) for impounding areas serving LNG containers with "over the top" fill and withdrawal connections with no tank penetrations below the liquid level, as the largest flow from any single line that could be pumped into the impounding area with the container withdrawal pumps considered to be delivering the full rated capacity for a duration of 10 minutes. For a design spill, NFPA 59A (2001 version) Section 2-2.3.1(a)(1) states that a thermal radiation flux rate of 5.05 kilowatts per square meter (kW/m^2)(1,600 British thermal units per hour per square foot [$Btu/hr/ft^2$]) not be exceeded at a property line that can be built upon. Because this facility is located offshore, there is no land area/property line affected by a design spill at the proposed facility. The proposed LNG tanks are all standard membrane tanks with primary and secondary barriers as required by the IGC. A design spill from external tank piping flows over the side of the FSRU into the ocean.

A design spill is further defined in NFPA 59A Section 2-2.3.3(d) for impounding areas serving only vaporization, process, or LNG transfer areas, as the flow for 10 minutes from any single accidental leakage source. Identified accidental leakage sources and their associated spill rates are set forth on Table 1-1.

Isolatable Sections	Largest Diameter	Flow Rate	Pressure	Associated Inventory (estimate)
LNG loading arms	16"	5,000 m^3/hr	Below 1 barg	25-30 m length of 16" diameter pipe (3 to 4 m^3)
LNG Cargo Tank loading header	32"	15,000 m^3/hr	Below 1 barg	350 m length of 32" diameter pipe (182 m^3)
LNG Cargo Tank production header	12"	2,460 m^3/hr	7 barg	450 m length of 12" diameter pipe (33 m^3) + HP pump inventory (1 m^3)
HP pumps	24"	365 m^3/hr	110 barg at the discharge	1 m^3
Vaporizer	24"	365 m^3/hr	110 barg	2.5 m^3
Recondenser			8 barg	40 m^3

Table 1-1: Summary of Accidental Leakage Sources

The largest possible accidental leakage source is the loading transfer line with a flow of 15,000 m^3/hr. Any accidental leakage is directed over the side of the FSRU through a spill containment deflector (*See* the drawings in the appendices, Section 13.4). The objective is to divert spilled LNG overboard as directly as practicable. The flow of spilled LNG impacts the design of the FSRU spill containment system.

Thermal Radiation Exclusion Zones

The regulations set forth in 49 CFR 193 require the establishment of a thermal exclusion zone for each LNG container and LNG transfer system, which is assumed for purposes of the FSRU to be a 500 yard safety and security zone based on typical USCG practice.

The thermal radiation exclusion zones were determined and associated calculations for the facility LNG spill scenarios were performed. These results are discussed in Section 13.4. The calculation details and supporting drawings are included in the appendices, Section 13.4.

These zones were calculated using the computer model LNGFIRE III as required by 49 CFR Part 193.2057 and NFPA 59A Section 2-2.3.1(b). The most restrictive process area 5 kW/m^2 thermal radiation exclusion zone distance is 396 yards (362 meters). All process area thermal radiation exclusion zones defined by 49 CFR Part 193 and NFPA 59A fall within an assumed 500 yard USCG safety and security zone. Isopleths for the site are illustrated in the appendices, Section 13.4.

The storage tanks for the LNG are designed using the codes and standards for gas carrier tanks. This facility is constructed to be a floating unit and is not located over land; therefore, thermal radiation flux calculations are not applicable for the LNG storage tanks.

13.1.2.2 Flammable Vapor Gas Dispersion Protection

49 CFR Part 193.2059 and NFPA 59A (2001 version) Section 2-2.3.2 require that provisions be made to minimize the possibility of a flammable mixture of vapors from a design spill reaching a property line that can be built upon. 49 CFR Part 193.2059(b)(1) further requires that the average gas composition in air at a property line that can be built upon not exceed 2.5 percent, which equals one-half the lower flammable limit (LFL). A design spill is as defined in Section 13.1.3 above.

An LNG spill is directed overboard and forms a pool on the ocean surface. The vapor dispersion zones for the facility LNG spill are shown in the calculations results included in the appendices, Section 13.4. These zones were calculated using the computer model DEGADIS, as required in 49 CFR Part 193.2059 and NFPA 59A Section 2-2.3.2(a). As input to the DEGADIS model, SOURCE5 was used. The program inputs include:

- Dimensions of the LNG tank;
- Properties of the liquid spilled;
- Properties of the ocean surface;
- Impoundment floor temperature; and
- Ambient conditions.

The model shows an excursion distance of 844 yards (772 meters) at the LFL and an excursion distance of 3489 yards (3190 meters) at 50% of the LFL for the pool of spilled LNG. As shown on the exclusion zone drawing in the appendices, Section 13.4, these exclusion distances do not fall upon any land area.

13.1.2.3 Soil Characteristics and Seismic Investigation

Soil and seismic input are required primarily for the design of the piled jacket structure and the piles themselves. The numerical and graphical seismic data are included in Resource Report 6.

13.1.2.4 Separation of Facilities

The FSRU layout is shown on the FSRU General Arrangement drawing provided in the Appendix Section 13.1 (312383–SAI–DWG 401.01). The proposed Broadwater FSRU LNG facility is permanently moored to a YMS in a water depth of approximately 28 m. The jacket mooring system is fixed to the seabed by means of steel piles. The FSRU weathervanes around theYMS, taking up a heading dependent on the wind and current forces.

The FSRU has a dedicated berth on its starboard side enabling the mooring of LNG carriers with capacities ranging from 125,000 m^3 to 250,000 m^3 LNG (*see* the drawings in the appendices, Section 13.17) in a side-by-side configuration. The loading arms are located on the starboard side, amidships. LNG is transferred through the loading arms and via the FSRU loading line header to the FSRU cargo tanks.

All the cargo piping is located on the portside at the FSRU trunk deck level. Main utility piping is also routed on the port side, the rest being installed within the inner trunk deck space.

The main process equipment for LNG and gas processing is located at the forward end of the FSRU. The equipment for superheating, metering, and odorization of the send-out gas is located at the forward end of the FSRU, and gas is transferred through jumpers to the pipeline riser located in the YMS.

The accommodation area, workshop, and CCR are located at the aft end of the FSRU as far as possible from hazardous equipment area (*see* the appendices, Section 13.1, General Arrangement). Process heaters are located in the hull for "ignition safety."

The power generation module is installed next to the accommodation area, above the hull machinery spaces. Utility systems are installed both within the hull and between the accommodation area and the aft cargo tank area, or above deck between the power generation and the loading platform. There is a distance of over 109 yards (100 meters) between the process facilities and the utility area.

The flare is located at the fore end of the cargo area of the FSRU and stands vertically above the trunk deck, on the port side, away from the LNG carrier berthing area.

13.1.2.5 Escape, Evacuation and Rescue (EER) Systems

The objective of the EER system is to ensure the safety of personnel when they have to, or decide to, move to another location to avoid the effects of a hazardous event. This objective applies equally to the localized effects of minor and major incidents that may require total abandonment of the FSRU.

The EER system is designed to:

- Enable personnel to safely leave any area where they may be affected by an incident;
- Enable personnel to get from any part of the facility that they are likely to occupy to the TR's;
- Create an area or structure that is protected from the effects of any potential incident for as long as is necessary for evacuation to take place;
- Secure communication to summon external assistance; and
- Enable evacuation from the FSRU.

The engineering of the EER system complies with goals and functional requirements defined in the EER Strategy and is based on a review of likely accidental scenarios, their duration and their severity. In addition, it takes into account the predicted response of individuals under emergency conditions.

The EER system is comprised of:

- The escape routes that allow personnel to escape from areas where accidental situations may arise and to join areas (i.e., TR or muster areas) in order to be protected from the potential effects of the accidental situation;

- The TR(s) where personnel can take refuge for a predetermined period while investigations, emergency response and evacuation preparations are undertaken;
- The primary and secondary means of evacuation that allow personnel to evacuate the FSRU in case of an accidental situation;
- The means of rescue that allow those who have entered the sea directly or in survival crafts/life rafts to be taken to a place where medical assistance is available;
- Miscellaneous safety and life-saving equipment to place onboard the FSRU to enable the EER of personnel; and
- A 100% capacity free-fall lifeboat aft of the accommodation, a 100% capacity free-fall lifeboat at the bow, and a fast rescue boat.

The Emergency Response Plan, which is yet to be fully developed and for which details are set forth in Resource Report 11, section 11.6, will include procedures for removing all personnel from the FSRU. The plan will address procedures with respect to, amongst others:

(i) FSRU sinking; and

(ii) Overwhelming FSRU fire which could not be controlled by FSRU staff or with the assistance of fire fighting tugs.

There are no credible weather conditions for which a complete removal of the crew is pre-planned. However, procedures will be developed in Broadwater's Emergency Response Plan such that in the event of a hurricane warning or similar situation, that may include a reduction in manning levels of non-essential staff (e.g. maintenance contractors) and a possible reduction in natural gas deliveries. Further information on this issue is set forth in Resource Report 11, sections 11.3.2.1 and 11.6.

Metocean conditions are discussed throughout this document and unless specified otherwise, it should be read that the metocean conditions are combined wave-current-wind conditions.

The decision to abandon the FSRU, however, will be at the discretion of the FSRU Port Superintendent in liaison with the shore support facility managers.

13.1.2.6 Temporary Refuge (TR), Muster Area and Shelters

During a general alarm, personnel muster at the TR of the installation (with the exception of the loading master who remains on the LNG carrier, if any is moored alongside).

The primary TR on the FSRU is the accommodation area. This TR has direct access to the life boats and requires a minimum area of 0.6 m^2 (6.5 ft^2) per person, per Safety of Life at Sea (SOLAS) and Class Rules.

A secondary TR is provided on the forward end of the FSRU, inside the bosun space. It is protected from flare radiation and from the effects of any process hazard scenarios that could impair the mustering at this location.

The TRs remain intact for the predicted evacuation times as per the EER study. Protection is required for this period from the effects of fire, explosion, unignited gas/smoke ingress and excessive heat.

Muster areas are considered to be impaired if:

- Heat radiation exceeds 1.6 kW/m2 (500 Btu/hr ft2);
- Blast overpressure exceeds 0.3 bar gauge (barg);
- Smoke levels lead to visibility below 5 m; or
- Unignited gas concentrations exceed 50% of the gas LFL.

An emergency command and control center is provided within the primary TR. Telephone and radio communication are provided to enable coordination of emergency response actions between the primary and alternative TRs. This center is protected to the same extent as the accommodation area. Emergency shutdowns (ESDs) may be initiated from any of the TRs.

13.1.2.7 Soft Yoke Mooring

The FSRU is connected by means of a soft YMS to a jacket, which is piled to the seabed. The jacket is a tubular steel space frame structure of square horizontal cross-section with legs in each of its four corners. At the base of the jacket there is a square mud mat, the corners of which are connected to the jacket legs. At each of the four mud mat corners there is a pile guide through which skirt piles are driven. A central column or 'king post' is located at the top of the jacket onto which the turntable is mounted. The turntable structure or 'topsides module' houses the swivel stack, and is connected by means of a slewing bearing to the top of the king post. This allows the FSRU, together with the mooring yoke to weathervane around the piled jacket.

The mooring yoke consists of a rigid triangular tubular structure which is connected at the jacket end by a roll and pitch articulation to the turntable, and at the FSRU end by two mooring legs to the MSS mounted on the FSRU's bow.

The transfer of send-out gas between the FSRU and yoke is achieved through a series of flexible jumpers which are suspended between the MSS and turntable structure. The jumpers are flexible pipes of a HP design that transport the gas to the gas swivel on the mooring tower. The gas then passes through the swivel assembly and into the pipeline riser, located within (and attached to) the mooring tower structure. Gas travels down the riser to the remainder of the pipeline system located on the sea floor. Although these components differ from the fixed pipeline system used with land-based LNG terminals, the components of the system perform the same transportation function, while allowing the FSRU to rotate around the fixed mooring tower. The mooring tower provides support to the pipeline riser and is configured to allow pipeline maintenance activities to occur (e.g., pig launching facilities are provided on the mooring tower). The interconnecting pipeline and the mooring tower are therefore part of an integrated system.

In addition to the jumpers, there is also a series of umbilicals (cables) which provide utilities to the YMS. This would include electrical power, compressed air, water, and control signals.

Further information regarding the soft YMS is provided in the appendices, Section 13.16.

13.1.2.8 Adjacent Activities

As a marine facility, there are no continuous adjacent activities. Marine activities do take place in the general area. An exclusion zone around the FSRU will be established as described above (*see* Thermal Radiation Protection) to ensure the safety of these activities.

Details of these on-water activities are set forth in Resource Report 8.

APPENDICES TO RESOURCE REPORT 13.1

13.2 FIRE PROTECTION SYSTEM

13.2.1 Design Rules and Regulations Summary

The following codes and standards are used in the design and operation of the fire protection systems for the FSRU:

- International Standards Organization (ISO) 13702, Petroleum and Natural Gas Industries – Control and Mitigation of fires and explosions on offshore production installations – Requirements and Guidelines, First Edition, 1999;
- NFPA 59A, Standard for the Production, Storage and Handling of LNG, 2001 Edition;
- 49 CFR Part 193, LNG Facilities: Federal Safety Standards, 2004 Edition;
- NFPA 10, Standard for Portable Fire Extinguishers, 2002;
- NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam Systems, 2005;
- NFPA 12, Standard on Carbon Dioxide Extinguishing Systems, 2005;
- NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection, 2001;
- NFPA 17, Standard for Dry Chemical Extinguishing Systems, 2002;
- NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection, 2003;
- NFPA 72, National Fire Alarm Code, 2002;
- NFPA 750, Standard on Water Mist Fire Protection Systems, 2003;
- American Bureau of Shipping (ABS) Classification Rules;
- International Convention for SOLAS, 1974 with Protocol of 1978, and the amendments of 1981, 1983, 1988, 1989, 1990, 1991, 1992, 1994, 1996, 1998 and 2000 including the International Life-saving Appliances Code (LSA Code), 1997; and
- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, (IGC), 1993.

The design of the fire protection systems for the hull and the accommodation area primarily follow LNG shipping practices, IGC requirements, and Class Rules.

13.2.2 Description of Fire Protection System

Fire protection zone drawings and the layout of fire protection systems are detailed on 312383-SAI-DWG-613 in the appendices, Section 13.2, and on 312383 – WSN – DWG - 611 in the appendices, Section 13.3. The Fire & Explosion Strategy Document is included in the appendices, Section 13.2. The Fire Protection Flow Schemes, Fire & Explosion Data Sheets, and the Fire & Explosion Assessment are included in the appendices, Section 13.2.

For structural fire protection boundaries, as is required of LNG carriers, an A-60 deck between living quarter and machinery/foredeck space according to SOLAS is fitted, duly insulated to meet A60 requirements. All the other boundaries are A-0 steel.

This is diagrammatically represented in Appendix 13.2.1

SOLAS A" Class Division" means a bulkhead or part of a deck which is:

(a) constructed of steel or other equivalent material;
(b) suitably stiffened;
(c) so constructed as to be capable of preventing the passage of smoke and flame to the end of the 60 minute standard fire test; and
(d) so insulated where necessary with suitable non-combustible materials that if the division is exposed to a standard fire test the average temperature on the unexposed side of the division shall not increase more than 139°C above the initial temperature nor shall the temperature at anyone point, including any joint, rise more than 180°C above the initial temperature within the time listed below:

A60 standard, 60 minutes
A30 standard, 30 minutes
A15 standard, 15 minutes
A0 standard, 0 minutes

General

The FSRU has specific fire protection systems for different areas of the facility. The fire system matrix below details which fire protection systems are used and in which areas.

	Fire Water Hydrant	Dry Powder	Water Spray	High Expansion Foam	Low Expansion Foam	Water Mist	Carbon Dioxide (CO_2)	Fresh-water Hydrant
Exposed deck in the cargo area	X	X						
Loading arms and cargo tank domes	X	X	X					
Process area			X					
Process area (HP LNG pump and vaporizers)		X	X					
Machinery space and process heater room (Except specified rooms)	X			X				
No. 1 and No. 2 low voltage (L/V) switchboard rooms							X	
No. 1 and No. 2 high voltage (H/V) switchboard rooms							X	
Emergency generator rooms						X	X	
No. 1 and No. 2 essential generator rooms						X	X	
H/V and medium voltage (M/V) transformer room							X	
Emergency switch board room							X	
Inert gas generator (IGG) room	X			X		X		
Accommodation area inside	X							X
Accommodation area front bulkhead			X					

	Fire Water Hydrant	Dry Powder	Water Spray	High Expansion Foam	Low Expansion Foam	Water Mist	Carbon Dioxide (CO_2)	Fresh-water Hydrant
Life boat embarkation area and escape route from the accommodation area			X					
Paint stores, acetylene room, and oxygen room							X	
Tower soft yoke areas			X					
Helideck	X				X			
Forward fire pump room	X						X	

13.2.2.1 Fire Water System

A seawater fire water system is provided for the facility. This supplies fire water to the largest demand case, which is defined as the largest fire area, plus the two largest adjacent areas. The main components of the fire water distribution system include:

- Two 100% fire water diesel-driven pumps;
- Two fire line vertical pressurizing jockey pump units, electrically-driven;
- Fire water piping distribution system (fire main system);
- Deluge valves for each identified fire area;
- Fire monitors;
- Fire hydrants; and
- Hose reels.

13.2.2.2 Dry Powder System

The objective of the dry chemical powder system is to extinguish LNG fires and prevent ignition of LNG leaks from storage tanks, loading arms, cargo handling/loading lines or other process lines.

Dry chemical powder is to be used for the control of fires in the following areas:

- Exposed cargo areas including LNG cargo tank domes (trunk deck);
- LNG cargo loading manifold area (trunk deck); and
- HP LNG pump/vaporizer area (process deck).

The FSRU is provided with one fixed dry chemical powder extinguishing system in accordance with the requirements of the IGC and Class Rules. The system comprises self-contained dry chemical powder units, pressurizing medium, fixed piping, monitors, and hand hose lines.

The dry chemical system details are shown on Drawing 312383-SHI-PFS-117 included in the appendices, Section 13.2.2.

13.2.2.3 High-Expansion Foam System

A high expansion foam fire extinguishing system is provided for fire fighting in the aft machinery space for complete coverage, including the process heater room.

The system consists of the following components:

- A foaming agent tank of steel construction with tar epoxy coating inside;
- Foaming agent;
- A foaming agent pump;
- A foam proportioner;
- Foam generators or foam distribution valves; and
- Other components (pipe, fittings, isolating valves, etc.).

Seawater for the high expansion foam system is supplied from a fire water pump.

The system details are shown on Drawing 312383-SHI-PFS-118 included in the appendices, Section 13.2.2.

13.2.2.4 Low-Expansion Foam System

The helideck fire protection conforms to SOLAS and Class Rules. It mainly consists of a low-expansion foam system with two fire monitors and hydrants supplied from the fire water distribution system provided for the FSRU.

The separate Aqueous Film Forming Foam (AFFF) system for the helideck is provided with monitors, hydrants, bladder tank, proportioners and controls. The system operates automatically and is charged by the fire main. The objective of the foam system is to extinguish jet fuel or lube oil fires.

13.2.2.5 CO_2 Fire Protection System

For electrical rooms within the hull or accommodation, dedicated carbon dioxide (CO_2) fire extinguishing systems are provided.

The CO_2 system details are shown on Drawing 312383-SHI-PFS-119 included in the appendices, Section 13.2.2.

13.2.2.6 Water Spray System

The water spray system for cooling, fire prevention, and crew protection is installed to cover:

- Exposed cargo liquid dome and vapor dome;
- Cargo loading arm valves;
- Essential cargo control valve; and
- Front bulkheads of accommodation deckhouse.

The system consists of a common fire water pump, spray main/branch pipes and nozzles made of brass. The main line is fitted with stop valves at intervals in order to isolate damaged sections.

The side shell water curtain headers for hull protection are provided on the starboard side on the upper deck adjacent to the cargo manifold area. The side shell water curtain headers are served by the fire main.

Provisions are made for freshwater flushing of all seawater spray systems.

The water spray system details are shown on Drawing 312383-SHI-PFS-120 and on Drawing 312383-SHI-PFS-123 included in the appendices, Section 13.2.2.

13.2.2.7 Water Mist System

A water mist system, to be used as a local application fire fighting system, is provided for the fire hazard portions of the emergency generator engine and IGG. It includes:

- Spray nozzles in the protected spaces;
- Both automatic and manual releasing method for each protected space;
- Isolating valve for each protected space, interfaced with the fire detecting system for automatic releasing;
- Freshwater supplied from FSRU's freshwater tank;
- Activation of any local application system, giving a visual and distinct audible alarm incorporated with light signal column in the protected space and at wheelhouse; and
- Pump unit and sectional valves placed in the machinery space or outside as per Class Rules.

13.2.2.8 Portable Extinguishers

Portable foam, CO_2, and CO_2 pressurized water fire extinguishers are supplied and are located at strategic positions throughout the FSRU. Extinguisher capacity and position is optimized for maximum effectiveness, and the type/content is selected for foreseeable fire scenarios.

All types of extinguishers are:

- Compliant with the relevant codes and standards;
- Capable of single person operation (whether portable or mobile); and
- Provided with weatherproof cabinets if externally located.

13.2.2.9 Passive Fire Protection

Fire ratings for hull bulkheads and accommodation bulkheads, decks, and deckheads are as per SOLAS and Class Rules at a minimum.

For equipment and structures within the process topsides, requirements for passive fire protection are reviewed in the Fire and Explosion Assessment, included in the appendices, Section 13.2.

13.2.2.10 Fire fighting Tugs

Firefighting capability is also provided via dedicated Project tugs. Details of the tug boat capabilities are set forth in Resource Report 11, section 11.4

13.2.2.11 On-water pool fires

On water pool fires may arise from a coincident large LNG spill and a local source of ignition. In general, this may be unlikely since LNG spills on water will evaporate and disperse quickly.

Response to an LNG spill that creates an on-water pool, particularly from the most likely source of an on-deck, low pressure system will be swift, such that the escaping LNG volume will be severely limited by rapid LNG system isolation, depressurization and electrical isolation of equipment via the Emergency Shutdown System (ESDS). Full details of the ESD System are set forth in Appendix 13.3.

Additionally, the most vulnerable areas of the LNG systems are provided with drainage to the (safe) port side of the FSRU away from process equipment and other equipment to an area where there is very little likelihood of the presence of a source of ignition. Further details of the spill containment philosophy and systems are set forth in Appendix 13.4.

The ESDS may be activated automatically via gas/fire detection systems or manual activation from several FSRU locations. Deck systems are visually and personally monitored at all times including via CCTV.

The FSRU is protected from an on-water pool fire by the following deck fire-fighting systems:

- Water spray to cover the deck and hull, thereby affording protection against structural damage;
- Fire water system to protect staff and complement FSRU hull cooling; and
- Firefighting assistance from tug boats.

The extent of cooling will depend on the intensity of the fire and its proximity to the FSRU. Additionally, the azimuth thrusters can be utilized to maneuver the FSRU away from the fire.

For an on-water pool fire in between the FSRU and an LNG carrier, the potential source of release is the loading system including the loading arms. Considering the industry record, a full bore rupture of the loading system is very remote.

During LNG offloading operations, water spray curtains are utilized both onboard the FSRU and the LNG carrier such that a continuous curtain of water protects the manifold area and hull side-shell from impairment by LNG. In this case, ESD systems may be rapidly (within seconds) deployed by activation of gas detection or manual push buttons available from numerous locations. LNG offloading and deck systems are visually and personally monitored at all times including via CCTV. Additional shut down arrangements for the loading/offloading systems in accordance with DEP 30.06.10.20 – Gen "ESD systems for loading and discharging refrigerated LNG and LPG carriers (e.g. excessive loading arm deflection) will be available for immediate ESD of all systems. As the ESD systems of the FSRU and LNG carrier are linked by fibre optic cable, both vessel and facility systems will be immediately shut down.

The ESD system, activated rapidly will:

- Shut down loading/offloading systems on FSRU and LNG carrier; and
- Isolate and disconnect the FSRU from the LNG carrier at the quick release coupling.

The mooring quick release hooks can be disconnected rapidly, leaving the LNG carrier to move away freely under its own power and assisted by standby tugboats. As an alternative to releasing QRHs, the LNG carrier winch brakes may be slipped, allowing the mooring wires to fall away from the LNG carrier. This has the advantage of reducing risk of wires fouling the LNG carrier propeller blades.

LNG carrier engines are maintained on immediate notice to start.

The ESD timeline is as follows:

0 sec	Detection and ESD activation;
30 sec	Cargo systems on FSRU and LNG carrier isolated;
1 min	Loading arms disconnected;
9 min	QRHs or LNG carrier winch brakes manually disconnected, LNG carrier engines ready for maneuvering; and
10 min	LNG carrier moves away from FSRU under its own power assisted by tugs as necessary.

APPENDICES TO RESOURCE REPORT 13.2

Fire Protection System Appendix

Appendix 13.2.1: Fire & Explosion Strategy

- FSRU Preliminary Layout / 312383 –SAI – DWG – 613
- Fire and Explosion Strategy /312383-SAI-SP-601
- Structural fire protection/312383-SHI-DWG-300
- A class insulation method - sample
- Fire protection Matrix

Appendix 13.2.2: Fire Protection Flow Schemes

- FSRU – PFS – Dry Powder System / 312383 - SHI-PFS-117.01
- FSRU – PFS-High Expansion Foam System / 312383 - SHI-PFS-118.01
- FSRU – PFS – CO_2 Fire Fighting System/ 312383 - SHI-PFS-119.01
- FSRU – PFS – Water Spray System/ 312383 - SHI-PFS-120.01
- FSRU – PFS – Fire Water System/312383 - SHI –PFS-123.01
- FSRU –PFS- Fire Water System Process Deck /312383 – SHI-UFD-601

Appendix 13.2.3: Fire & Explosion Data Sheets

- Data sheet for dry powder/312383-SHI-DS-101
- Data sheet for high expansion foam/312383-SHI-DS-102
- Data sheet for low expansion foam/312383-SHI-DS-103

Appendix 13.2.4: Fire & Explosion Assessment

- FSRU 6.3 kW/m^2 Radiation Contours for 7mm hole sizes/ 312383 -SAI-DWG-620.01
- FSRU 6.3 kW/m^2 Radiation Contours for 19mm hole sizes/ 312383 – SAI-DWG-620.02
- FSRU 6.3 kW/m^2 Radiation Contours for 50mm hole sizes/ 312383 – SAI-DWG – 620.03
- FSRU 6.3 kW/m^2 LFL Contours for 7mm holes sizes / 312383-SAI-DWG-620.04
- FSRU 6.3 kW/m^2 LFL Contours for 19mm holes sizes/312383-SAI-DWG-620.05
- FSRU 6.3 kW/m^2 LFL Contours for 50mm holes sizes/312383-SAI-DWG-620.06
- FSRU 15 kW/m^2 Radiation Contours for 7mm hole sizes/312383-SAI-DWG-620.07
- FSRU 15 kW/m^2 Radiation Contours for 19mm hole sizes/312383-SAI-DWG-620.08
- FSRU 15 kW/m^2 Radiation Contours for 50mm hole sizes/312383-SAI-DWG-620.09
- Coarse Fire & Explosion Assessment/312383-SAI-REP-604

13.3 HAZARD DETECTION SYSTEMS

13.3.1 Design Rules and Regulations Summary

The following codes and standards are used in the design and operation of the hazard detection systems for the FSRU:

- 33 CFR Part 127, Water Front Facilities Handling LNG and Liquefied Hazardous Gases;
- American Petroleum Institute (API) RP 14C, "Recommended Practice for Analysis Design, Installation and Testing of Basis Surface Safety Systems for Offshore Production";
- ISO 13702, Petroleum and Natural Gas Industries – Control and Mitigation of Fires and Explosions on Offshore Production Installations – Requirements and Guidelines, First Edition 1999;
- NFPA 59A, Standard for the Production, Storage and Handling of LNG, 2001 Edition;
- 49 CFR Part 193, LNG Facilities: Federal Safety Standards, 2004 Edition;
- NFPA 72, National Fire Alarm Code, 2002;
- SOLAS, ABS Class Rules; and
- IGC Code.

13.3.2 General

The Preliminary Layout of the Hazard Detection Systems is set forth on Drawing 312383-WSN-DWG-611, in the appendices, Section 13.3. In addition, the Philosophy for Alarm Management with respect to the Fire and Gas (F&G) and ESD Systems/312383-SAI-SP-605 also is provided in appendix Section 13.3.

Hazard detection for the facility is designed based on the following strategies:

- Direct visual monitoring (by personnel);
- Remote visual monitoring through closed circuit television (CCTV);
- Automatic detection (fire, flame, gas, smoke and low temperature);
- Centralized alarm system; and
- ESD system.

A Distributed Control System (DCS) provides the primary interface between the operators and the plant. The DCS is supplemented by independent safety systems to detect potentially hazardous conditions and protect personnel, facility assets and the environment. An Instrumented Protective System (IPS) is provided to safeguard personnel and the plant against process upsets, including equipment failures.

An independent ESD is provided to bring the plant to a safe state in the event of an escalation. The ESD is meant to implement high-level shutdown actions. It does not rely on functions controlled by the regular control system.

49 CFR Part 193 and NFPA 59A both require all areas that have a potential for combustible gas concentrations of LNG or flammable refrigerant spills to be monitored for combustible gas concentrations. A Fire and Gas Detection System (FGS), independent from the DCS, is provided to raise alarms at appropriate locations throughout the FSRU and initiate remedial actions via the IPS and ESD, as appropriate. The FSRU has dedicated monitoring systems for fire, combustible gas, and low temperature LNG spillage detection. Audible and visual alarms are provided throughout the terminal area. The monitoring system is self-contained and connected to the DCS.

All area detectors are hardwired from the field device to a control room panel. Fire monitors (ultraviolet/infrared [UV/IR]) and gas detectors are equipped with self-diagnostic circuitry to assure proper device operation. Instrumentation is rated to meet the hazardous area classifications. In general, instrumentation is provided to meet the International Electrical Code (IEC).

A comprehensive CCTV system is provided for monitoring vulnerable areas, including:

Audible and visual alarms are announced both outdoors in the process areas, on the YMS, and inside the accommodation area and machinery spaces.

Detailed information on the ESD and FGS is provided in Document 312383-SAI-SP-605-"Philosophy for Alarm Management, FGS and ESD Systems," included in the appendices, Section 13.3.

13.3.3 Prevention Measures

Early detection and isolation of hazardous releases and reduction of certain hazardous inventories can substantially limit the consequences resulting from an emergency situation such as a major release of flammable material or hydrocarbon or a fire. Safety systems are provided for situations where rapid isolation of an uncontrolled release is desirable to shut off secondary fuel sources that could feed a fire or vapor cloud.

13.3.3.1 Minimizing LNG Inventory

The most significant hazard distances are associated with HP jet LNG releases. Typical dispersion distances to the LFL and flame sizes are proportional to the square root of the release rate. For a similar hole size and pressure, a flame is approximately five times bigger for LNG than for NG.

The LNG inventory on the facility deck is minimized. Apart from the process low pressure (LP) systems and piping, the only sources of LNG on the deck are the vaporizers and recondenser. In the case of an emergency, LNG in the piping, recondenser and loading arms gravity drains to the LNG tanks. The gas volume in a typical vaporizer is small, approximately 2.5 m^3. The vaporizer has a high design pressure (110 bar), and can be shut-in in the case of an emergency. The valves used to isolate the LNG systems can be closed in less than 30 seconds.

13.3.3.2 Leak Source Control

Spill collection is only meaningful for liquid spills. All NG and LNG leaks under high pressure do not result in liquid pools. The LNG atomizes and vaporizes without collecting in pools on the deck. The facility has two pressure levels: 6-10 bar and above 100 bar.

Only leaks from the 6-10 bar sections of the piping could lead to a partial rainout of spills. Small leaks from flanges or instrument lines do not damage the structure or cause escalation. Large leaks are collected using spill containment channels and directed overboard away from process equipment to vaporize and disperse.

In order to reduce the occurrence of leaks, the number of flanges and small bore piping connections is minimized, although flanged joints are unavoidable at several locations such as:

- the connection at the end of the loading arms;
- the top flange of the in-tank pump wells; and
- every pipe entry into all tanks.

13.3.3.3 Ignition Source Control

Instrumentation and equipment is designed for the appropriate area classification as shown on Drawing 312383-WSN-DWG-610, included in the appendices, Section 13.11. This minimizes the risk of fire from an electrical source.

13.3.4 Low Temperature Detection

Low temperature detectors are used to rapidly detect LNG spillage in areas where such releases may occur and accumulate. The low temperature detectors are complementary to the gas detectors. Low temperature detectors are provided in the loading arm area, cargo tank liquid domes, and recondenser area.

The coverage areas are shown on Drawing 312383-WSN-DWG-611, included in the appendices, Section 13.3.

13.3.5 Flammable Gas Detection

In general, line-of-sight IR gas detectors are installed for outdoor areas in combination with point IR gas detectors. For enclosed spaces and HVAC air inlets, point IR gas detectors only are installed. Gas detectors are provided in the following locations:

- Loading arm area;
- Cargo tank domes;
- BOG compressor building;
- Recondenser area;
- LNG HP pumps and vaporizer area;
- Metering and odorization units;
- YMS swivel stack;
- YMS manifold deck;
- End connections of FSRU to yoke tower sendout gas flexibles;
- Air Intakes to rotating machinery;
- Air Intakes to process heaters; and
- Air Intakes to accommodation and hull machinery spaces and bosun space.

Confirmed gas detection consists of two IR gas detectors on 50% LFL alarm. These may be either IR point gas detectors or line-of-sight gas detectors. On single gas detection at 50% LFL in the air inlets, the HVAC systems and the associated fire dampers are closed and an alarm is raised in the CCR. Input from the FGS is used to initiate ESD actions.

The coverage areas are shown on Drawing 312383-WSN-DWG-611, included in the appendices, Section 13.3.

13.3.6 Fire Detection

An FGS is provided for the FSRU to provide continuous monitoring functions to alert personnel of the presence of a fire. It is independent from the process control system and is an integral part of the FSRU safety system along with the ESD and Blow-Down Systems. The FGS collects and displays alarms in the CCR and other locations to be determined during the detailed design phase. Input from the FGS is used to initiate ESD actions.

13.3.6.1 Flame Detectors

In general, IR flame detectors are used for coverage of process equipment. The following areas are provided with IR flame and gas detectors:

- Loading arm area;
- BOG compressor building;
- Recondenser area;
- LNG HP pumps and vaporizer area;
- Metering and odorization units;
- YMS manifold deck; and
- YMS swivel stack.

The coverage areas are shown on Drawing 312383-WSN-DWG-611, included in the appendices, Section 13.3.

13.3.6.2 Heat Detectors

Heat detectors are used to detect the probable presence of fire. Heat detectors are provided in the following areas:

- Electrical rooms in the accommodation area;
- Workshop;
- Diesel system in the machinery spaces (diesel purifier room, diesel generators);
- Galley; and
- Above large power transformers (oil-filled type).

The coverage areas are shown on Drawing 312383-WSN-DWG-611, included in the appendices, Section 13.3.

13.3.6.3 Smoke Detectors

Smoke detectors are used within electrical rooms and facility enclosed spaces (this does not apply to continuously manned rooms such as the CCR). For normally unmanned rooms containing sensitive electrical equipment (switchgear rooms, auxiliary rooms, computer rooms, telecom rooms, etc.), a High Sensitivity Smoke Detection System is provided to ensure very early fire fighting response. The following areas are provided with smoke detectors:

- Electrical rooms including false ceilings and false floors;
- Air intakes to accommodation and hull machinery spaces; and
- Accommodation area (cabins, galley, etc.).

The coverage areas are shown on Drawing 312383-WSN-DWG-611, included in the appendices, Section 13.3.

13.3.7 Escalation Control

In the event that the DCS fails to keep the process within specified operating limits, separate, dedicated safety systems, such as the ESD system, are provided for the safe shutdown of equipment and or process units. The ESD is used to implement high level shutdown actions. It includes dedicated process sensors that activate the different ESD actions as required and does not rely on functions controlled by the regular control system.

13.3.8 Alarm Systems

Different alarm information will be announced through the Public Address (PA) system:

1st level alarms:
- Process shutdown alarm, and
- Low level gas alarm.

2nd level alarms – emergency alarms:
- Confirmed gas alarm,
- Confirmed fire alarm, and
- ESD alarm.

3rd level alarm – abandon facility alarm.

Each of these alarms is associated with a type to be defined during detailed design (Hi-Lo or monotone for example). These alarms are supplemented by visual alarms in noisy areas (gas turbines for example). These visual alarms are also associated with a color code to be defined during detailed design (yellow, red or blue).

Locations of alarm pull stations are shown on Drawing 312383-WSN-DWG-611, included in the appendices, Section 13.3.

Hazard detection automatic signals such as detection alarms, monitoring signals or CCTV signals will be restricted to on-board FSRU hazard detection and control systems and personnel. No automatic signals will be sent directly to shore support facilities. In the event of hazardous situations arising, FSRU personnel will be required to report to a shore support facility and to the appropriate shore authorities as part of the Emergency Response Plan, which is yet to be fully developed and for which details are set forth in Resource Report 11, Section 11.6.

13.3.9 LNG Storage tank spill/leak detection

Spill or leakage from the LNG storage tanks can be detected via several means. The leak detection is primarily fitted to the membrane barrier spaces rather than detection equipment installed in adjacent ballast tanks. Any vapor leakage across the primary (or secondary) membrane can therefore be detected as early as possible.

Gas detection

A remote gas detection system is fitted which enables drawing of interbarrier (IBS) and insulation space (IS) atmosphere samples to a central redundant Class approved IR type fixed gas detection system located in a safety zone and linked to alarms in the CCR, such that any leakage across the primary (or secondary) membrane can be detected at very low levels. This is the principle detection system for vapour leakage across the membranes.

Temperature detection

The cofferdams, interbarrier spaces and insulation spaces are fitted with redundant temperature sensors. The primary means of low temperature detection is via of temperature sensors distributed and are linked to alarms in the CCR. For cofferdams and upper and lower inner hull steel, temperature sensors are primarily used for temperature control and comprise temperature sensors

Other indicators of gas detection in addition to the above may include interbarrier space and insulation space pressure control systems which will exhibit abnormal pressure control symptoms such as excessive IBS and IS venting.

Further information on the above is set forth in Appendix 13.10.1 and in Appendix 13.9.3

APPENDICES TO RESOURCE REPORT 13.3

Philosophy for Alarm Management, F&G and ESD Systems / 312383-SAI-SP-605
Hazard detection systems matrix
Hazard detection systems 312383-wsn-dwg-611-1
Hazard detection systems 312383-wsn-dwg-611-2
Hazard detection systems 312383-wsn-dwg-611-3
Hazard detection systems 312383-wsn-dwg-611-4
Hazard detection systems 312383-wsn-dwg-611-5
Hazard detection systems 312383-wsn-dwg-611-6
Hazard detection systems 312383-wsn-dwg-611-7
Hazard detection systems 312383-wsn-dwg-611-8
Hazard detection systems 312383-wsn-dwg-611-9
Hazard detection systems 312383-wsn-dwg-611-10
Hazard detection systems 312383-wsn-dwg-611-11
Hazard detection systems 312383-wsn-dwg-611-12
Hazard detection systems 312383-wsn-dwg-611-13
Hazard detection systems 312383-wsn-dwg-611-14
Hazard detection systems 312383-wsn-dwg-611-15
Hazard detection systems 312383-wsn-dwg-611-16
Hazard detection systems 312383-wsn-dwg-611-17
Hazard detection systems 312383-wsn-dwg-611-18
Hazard detection systems 312383-wsn-dwg-611-19
Hazard detection systems 312383-wsn-dwg-611-20
Hazard detection systems 312383-wsn-dwg-611-21

13.4 SPILL CONTROL SYSTEM

13.4.1 Design Rules and Regulations Summary

The following codes and standards are used in the design of the LNG storage and spill containment detection systems for the FSRU:

- 33 CFR Part 127, Water Front Facilities Handling Natural Gas and Liquefied Hazardous Gases;
- NFPA 59A, Standard for the Production, Storage and Handling of LNG, 2001 Edition;
- 49 CFR Part 193, LNG Facilities: Federal Safety Standards, 2004 Edition;
- ABS Class Rules; and
- IGC Code.

13.4.2 General Overview

The design of the spill containment systems is shown on Drawing 312383-WSN-DWG-612 included in the appendices, Section 13.4. The design of the Hull Part Drainage System is shown on Drawing 312383-SHI-DWG-411 included in the appendices, Section 13.4.

The FSRU houses eight LNG storage tanks of the marine membrane type with a total net storage capacity of 350,000 m^3. The storage tanks for the LNG are designed using the proven marine membrane-type codes and standards for gas carrier tanks.

The FSRU process equipment is located on the deck above the top of the LNG storage tanks. The FSRU is located offshore, with no adjoining properties.

Any spilled LNG is diverted over the side of the FSRU away from the manifold side to form a pool on the surface of the surrounding ocean. Thermal radiation and vapor dispersion modeling is performed for a guillotine break of the largest lines involved and also for jet releases from the high pressure lines. *See* Section 1 of this Resource Report for more information on Thermal Radiation and Vapor Dispersion.

There are mainly three potential sources for LNG spillage:

- LNG loading arms;
- LNG LP systems (below 10 barg): cargo piping and recondenser; and
- LNG HP system (above 100 barg): HP pumps/vaporizers.

13.4.3 Process Overview

The LNG brought by the LNG carrier is loaded through four loading arms. There are two liquid arms, one vapor return arm and one spare liquid/vapor arm. Assuming that the installed spare arm is used, a maximum loading rate of 15,000 m^3/hr (5,000 m^3 per arm) can be achieved.

For send-out, LNG is pumped from the cargo tanks with in-tank LP pumps to HP pumps that feed the vaporizers. The vaporized NG is then heated to a temperature specification (39°C to 62°C depending on the send-out rate), odorized and metered before send-out. The average send-out rate is 1.18 Mm^3/hr (1Bcfd). The minimum and maximum send-out pressures are 52 barg and 100 barg.

Below is a summary table of the different process sections carrying LNG.

Isolatable Sections	Largest Diameter	Flow Rate	Pressure	Associated Inventory
LNG loading arms	16"	5,000 m^3/hr	Below 1 barg	25-30 m length of 16" diameter pipe (3 to 4 m^3)
LNG cargo tank filling header	32"	15,000 m^3/hr	Below 1 barg	350 m length of 32" diameter pipe (182 m^3)
LNG cargo tank production header	12"	2,460 m^3/hr	7 barg	450 m length of 12" diameter pipe (33 m^3) + HP pump inventory (1 m^3)
HP pumps	24"	365 m^3/hr	110 barg at the discharge	1 m^3
Vaporizer	24"	365 m^3/hr	110 barg	2.5 m^3
Recondenser			8 barg	40 m^3

Table 4-1: Process Sections Carrying LNG

13.4.4 Drainage for LNG Spills

The loading arm areas are provided with an appropriate coaming and draining system that diverts LNG spillage to the ocean. The disposal point is selected so that the flammable gas cloud formed from the LNG pool over the ocean should not migrate to the space between the sides of the FSRU and the LNG carrier. LNG spills from loading arms are also mitigated using the standard LNG carrier approach of stainless steel cladding part of the FSRU hull at the loading points, combined with a fit-for-purpose water spray system.

Noticeable potential sources for LNG release are the cargo tank domes where piping enters and comes out of the cargo tanks and where flanged isolation valves are installed. The domes are located along the central axis of the FSRU. Piping and flanging are arranged in such a way (i.e., with sufficient height from trunk deck) that any leak is contained within the dome area, collected and gravity drained to the FSRU port side, also taking into account possible list and roll movements. Furthermore, the domes are provided with appropriate coaming and a diverter channel transverse to the FSRU directing any LNG spillage overboard on the port side. The diverter channel is not covered, and is as narrow as possible, while allowing the gravity drainage of the largest design release rate.

The recondenser is located on the FSRU port side, close to the outboard edge. It is also fitted with an appropriate coaming system and a transverse diverter channel that directs any LNG spillage overboard on the port side.

HP pumps and vaporizers are located on the port side of the FSRU, as close as practicable to the outboard edge to make the spilled LNG travel to the overboard disposal as short as possible. This area has appropriate coaming and a diversion system similar to that described above.

In addition to the LNG spill control systems discussed herein, the FSRU facilities are equipped with fire and gas detectors that monitor all process and storage areas and alert the operator in a timely manner at the start of any LNG release. Typically, these systems have automatic shutdown protocols to initiate the appropriate executive actions to minimize the release quantity and extent.

After shutdown valves have isolated all process sections, residual LNG drains from the leaking pipe work section or equipment. In addition, low temperature detectors are installed at potential accidental release locations and at local accumulation points, as shown on the preliminary layout for spill containment systems.

The area of the Yoke Mooring System is not adjacent to any LNG sources and only carries vaporized natural gas. As such, the YMS structure will not be threatened or affected by LNG. It is however, provided with water spray system as described in section 2 of this report, which may be used to protect the YMS structure in the unlikely event that it is threatened by LNG.

In summary, the FSRU and YMS are protected from LNG spills by:

- Hull material selection;
- A comprehensive fire and gas detection system;
- A comprehensive low temperature detection system;
- A comprehensive ESD system;
- Coaming and drainage channels for potential FSRU spill zones directed away from the hull; and
- Water curtain and spray systems.

13.4.5 Thermal Exclusion Zones

The Thermal Exclusion Zones are shown on Drawing 312383-PTL-DWG-601 in the appendices, Section 13.4. The thermal exclusion zones for the FSRU were calculated from a pool fire of the largest spill of LNG and were calculated using the computer model LNGFIRE III, dated 4/4/1996. The pool fire case was run for an ignited spill through a 32-inch opening. Alternate cases were also run for a 16-inch opening and jet fire release through a high pressure (110 barg) 50 mm opening.

The worst weather conditions that occur at the site at least 95% of the time must be used for the thermal radiation calculation. The weather data used to calculate the thermal radiation analysis of this site were derived from recorded data for La Guardia airport in New York City and include:

- Wind Speed 12 m/sec
- Ambient Temperature -10°C
- Relative Humidity 80%

The LNGFIRE III report, 312383-PTL-REP-601, is included in the appendices, Section 13.4.

The thermal radiation isopleth distances for the LNG pool fire are provided below:

Thermal Flux (kW/m^2)	32 inch opening - Distance from Center of the Pool (m) (Size – 48 m)	16 inch opening - Distance from Center of the Pool (m) (Size – 24 m)	50 mm opening - Distance from Center of the Fire (m) (No pool)
Scenario	Loading Arm Manifold Break	Loading Arm Break	50 mm Hole in HP LNG Piping
Discharge Rate (kg/sec)	3190	797.5	26.6
Pool radius (m)	48	23.9	No Pool
Thermal Flux - 5.0 kW/m^2	362	207	49
Thermal Flux - 9.5 kW/m^2	316	182	34
Thermal Flux - 31.5 kW/m^2	257	151	<10

Table 4-2: Thermal Radiation Isopleth Distances for the LNG Pool Fire

13.4.6 Vapor Dispersion Zones

The DEGADIS program is recognized by the NFPA 59A and 49 CFR Part 193 codes for vapor dispersion calculations. There are several input parameters required for the DEGADIS model. Credible, adverse conditions and site atmospheric conditions are required to be used for the analysis. The conditions used for this analysis include:

- Stability class F;
- Surface roughness 0.01 m for spills on water;
- Wind speed of 2 m/s;
- Temperature atmospheric: 10.5 °C;
- Temperature surface: 10.5 °C;
- Humidity: 75%; and
- Vapor generated – methane.

The spill is modelled as a continuous unconfined spill of the full flow from the loading line in way of the loading arms on the starboard side of the FSRU. The spill forms a pool on the surface of the ocean. Calculations for the spill are run assuming that the full flow from the pipe rupture is vaporized for the 15,000 m^3/hr and 5,000 m^3/hr cases. The jet release model does not show a flammable concentration at ground level for either of the two flows.

The SOURCE5 and DEGADIS output files and the isopleths are provided in Report 312383-PTL-REP-601, and on Drawing 312383-PTL-DWG-602 in the appendices, Section 13.4.

The vapor dispersion isopleth distances for the LNG spill over water are:

Concentration	15,000 m^3/hr - Distance from Edge of the Pool (m)	5,000 m^3/hr - Distance from Edge of the Pool (m)	Jet Release - Distance from Edge of the Pool (m)
Scenario	Loading Arm Manifold Break	Loading Arm Break	50 mm Hole in HP LNG Piping
Discharge Rate (kg/sec)	3190	797.5	60.6
Pool radius (meters)	40.0	29.6	No Pool
.025 – ½ LFL Concentration *	3939	3411	No flammable concentration reported at ground level
.050 – LFL Concentration *	772	621	No flammable concentration reported at ground level

Table 4-3: Vapor Dispersion Isopleth Distances for the LNG Spill over Water

* The LFL for methane in air is at a concentration of 5% methane gas.

13.4.7 Sandia Report Applicability

Details of the applicability of the Sandia Report are contained in Resource Report 11, Section 11.3. Site specific modelling is also contained in this Resource Report 13 Appendix 13.4 – DNV Report 70012855 Rev2, Section 7.

APPENDICES TO RESOURCE REPORT 13.4

Spill Control and Containment Philosophy / 312383-SAI-SP-603
Hull Part Drainage System / 312383-SHI-DWG-411.01
LNG Vapor Dispersion and Thermal Radiation Calculations / 312383-PTL-REP-601
Thermal Radiation Isopleths / 312383-PTL-DWG-601
Vapor Dispersion LFL Contours / 312383-PTL-DWG-602
Thermal Radiation Calculations / 312383-PTL-SP-603-X1
Vapor Dispersion Calculations / 312383-PTL-SP-603-X2
DNV Report 70012855 Rev 2
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 1 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 2 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 3 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 4 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 5 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 6 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 7 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 8 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 9 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 10 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 11 of 12
FSRU Preliminary Layout LNG Spill Control Systems / 312383-WSN-DWG-612, 12 of 12

13.5 SHUT-OFF VALVE

13.5.1 Design Rules and Regulations Summary

Applicable rules and regulations are:

- 33 CFR Part 127, Water Front Facilities Handling LNG and Liquefied Hazardous Gas;
- 33 CFR Part 149, Deepwater Ports: Design, Construction, and Equipment; Subpart B, Pollution Prevention Equipment; Subpart D, Fire-fighting and Fire Protection Equipment; and Subpart F, Design and Equipment;
- API RP 14C, "Recommended Practice for Analysis, Design, Installation and Testing of Basis Surface Safety Systems for Offshore Production;" and
- NFPA 59A, Standard for the Production, Storage and Handling of LNG, 2001 Edition.

13.5.2 ESD System

In the event the DCS fails to keep the process within specified operating limits, separate, dedicated safety systems are provided for the safe shutdown of equipment and/or process units. The ESD system is one such system and is described in detail in document 312383-SAI-SP-605, included in the appendices, Section 13.3.

ESD implements high level shutdown actions. It includes dedicated process sensors that activate the different ESD actions, as required. It does not rely on functions controlled by the regular control system.

The ESD system consists of:

- Safety dedicated sensors;
- Manual stations strategically positioned within the FSRU facilities;
- Control cabinets and computerized system to monitor the sensors, process the output signals, activate the necessary executive actions and interface signals to other systems as required for the aimed shutdown;
- Human-machine interfaces in the CCR and other selected locations comprising status and alarm displays on operator stations and mimic panels to raise alarms; and
- Safety dedicated actuators such as shutdown valves.

These ESD system components do not replace any requirements for providing pressure safety valves; rather, they are a supplement to relief valve protection.

Diagrams that show the ESD system are included in the appendices, Section 13.5. ESD Flow charts ESD 0; ESD 1; ESD2 are contained within 312383-SAI-REP-501.01~03.

13.5.3 Emergency Depressurizing

A blow-down system is integrated with the ESD system. It comprises the Blow-Down Valves (BDVs) fitted to the gas-handling sections, the blow-down header, and the flare system. Any isolatable section of gas carrying pipe or equipment is fitted with a BDV.

The blow-down header collects the discharged gases to the flare where they are ignited. The blow-down and flare systems are designed to satisfy the API RP 521 criteria of reaching 7 barg or half the maximum operating pressure (whichever is the lowest) in 15 minutes.

An ignitable flare is provided to safely dispose of emergency process releases. Under normal operating conditions, the facility has zero flaring (the BOGs are entirely recondensed to LNG and routed to the LNG HP pumps except when the send-out is shut down); and consequently, the flare has no pilot flame. In emergency depressurization, the flare is required to be automatically ignited prior to gas discharge.

Flare heat radiation is evaluated based on depressurization design cases to enable adequate location and height of the flare structure with regard to surrounding critical facilities (including the YMS, escape routes and TR at forward end, send-out equipment, and the LNG carrier berthed alongside).

13.5.4 Shut-off Valves

The FSRU has isolating valves (SDVs) that are closed upon ESD. The SDVs are not always dedicated ESD valves, and such SDVs have separate actuation modes for ESD and normal process usage.

SDVs are typically of a fail-safe type and a de-energize-to-trip approach is generally adopted. The SDVs are not provided with a hand-wheel. Process control valves are not used as shut-off valves.

The valves are fire-safe valves with piston actuators. A spring closes the valve upon loss of pressure. Actuation involves energizing a solenoid valve, which puts pressure on the valve operator opening the valve. When an ESD is activated, the pressure is released and the fail close spring closes the valve. A manual reset is required to initiate reopening of the valve. This assures that an operator has first hand knowledge of the condition of the facilities prior to reactivation. The valves are also equipped with position switches that display the position of the valves in the control room.

The ESD valves are supplied with manual reset solenoid valves, on-line test panels, open/close position switches, fireproof enclosures, and fail close operation. Valves are tested for Class 6 leakage, fire safe and cryogenic service. All cryogenic ESD valves are butt-welded to process piping.

The philosophy for alarm management, F&G, and ESD systems (312383-SAI-SP-605) is included in the appendices, Section 13.3.

Shut down valves are designed, manufactured, and tested to comply with ASME B31.3.
Valve operation (testing, ESD, process trip, indication) is as per Type 6 of appended drawing 312383-SAI-DWG-501. A closure time of ½ second is anticipated.

Valve arrangement or equivalent is shown on attachment NPS 16 BW

Typical actuator or equivalent is described in the appended LNG actuator

Typical position monitoring (or equivalent) is described in the appended .

APPENDICES TO RESOURCE REPORT 13.5

Emergency Shut Down Flow charts EDS 0; ESD 1; ESD2 / 312383-SAI-REP-501.01-03
Typical Fail Safe Shut-off Unloading Valves Arrangement / 312383-SAI-DWG-501
NPS 16 BW Vanessa with Actuator
LNG Actuator
Accutrak Rotary Positioner

13.6. FUEL SYSTEMS

13.6.1 Fuel Gas

13.6.1.1 Design Rules and Regulations Summary

The applicable codes and standards are:

- Tubular Exchangers Manufacturers Association (TEMA): Standards for Shell and Tube Heat Exchangers (Fuel Gas Heaters); and
- IGC for the part of the system inside the hull (includes fuel gas double piping line).

13.6.1.2 Fuel Gas System Description

The fuel gas system drawings are set forth in the appendices, Section 13.6.1.

The fuel gas system is designed to supply gas at an acceptable flow rate and temperature to the gas turbine generators and the process heaters. The minimum required fuel gas temperature for the process heaters and the gas turbines is typically between 15°– 21°C (60°– 70°F). The HP fuel gas required for the gas turbines is taken from the inlet header to the sales gas meters. It will be metered separately. The fuel gas is pre-heated prior to reducing the pressure from 100 barg to about 28 barg. The primary source of the LP fuel gas required for the process heaters is from the BOG compressor discharge header. The secondary source of LP fuel gas is from the HP fuel gas system. The fuel gas is pre-heated and reduced to about 1.7 barg (25 pounds per square inch gauge [psig]).

13.6.2. Diesel Oil

13.6.2.1 Diesel Oil System Description

The diesel oil (DO) system drawings are set forth in the appendices, Section 13.6.2.

A DO system is provided for the gas turbine generators, essential diesel generator engine, emergency generator engine, IGG and diesel-driven fire pumps. The DO system consists of a DO transfer system, purifying system, service system, and drain system.

Utility machinery and the design of associated piping systems are prepared to use low sulfur automotive diesel. DO is supplied to the FSRU by supply boat, and DO bunkering is of local manual control. The emergency shut off valves in the machinery space are controlled from the "fire control center."

Copper or copper bearing alloys are not used for the DO system or the DO equipment to the extent practicable.

Diesel Oil Filling/Transfer and Drain System

The DO transfer pump takes suction from machinery space, DO storage tanks and the DO overflow tank, and discharges to the DO service tank and the Emergency Diesel Generator (EDG) DO tank. One strainer of a duplex type is fitted at the suction side of the DO transfer pump. Overflow pipe of the DO storage tank is led to the DO overflow tank. The overflow line of the DO storage tank is fitted with a sight glass. The DO service tank is fitted with a drain valve of a self-closing type. Below the valve on the tanks, an oil coaming is arranged and drains from the oil coaming feed to the oily bilge tank. The DO drains from the base plates for the DO transfer pump, and Clean Leakage Oil from the EDG engine is fed to the DO overflow tank.

The sludge pump takes suction from the DO sludge tank or the oily bilge tank and discharges to shore connections on the upper deck. One strainer of a duplex type is fitted at the suction side of the sludge pump.

Diesel Oil Purifying System

A DO purifier is installed in a purifier room fitted with a lifting I-beam, a gas-tight entrance, and an exhaust fan. One strainer of a duplex type is provided at the suction side of the feed pump. The DO in the DO storage tank is fed to the DO purifier, and the DO purifier discharges clean oil to the DO service tank. Water and sludge separated from the DO are fed to the DO sludge tank.

Gas Turbine Generator Diesel Oil Service System

The DO system for gas turbine generators is designed to burn the DO as the secondary fuel. The DO system is designed according to the gas turbine generator manufacturer's standards.

Essential Generator Engine Diesel Oil System

The DO system for the essential diesel generator engine is designed to burn the diesel oil according to the engine manufacturer's standards. The DO for diesel generator engines is fed from the diesel generator and gas turbine DO supply pump depending on the machinery arrangement under the manufacturer's confirmation.

Emergency Generator Engine Diesel Oil System

The DO system for the emergency diesel generator engine is designed to burn the DO according to the engine manufacturer's standards. The DO for emergency generator engine is fed from a separate DO tank and can be supplied from the DO storage tank using the DO transfer pump for emergency use.

Diesel Oil Drain System

All machinery oil drains lead to a waste oil tank. The oil is then transferred and shipped by boat to an approved on-shore reclamation/disposal facility. No oil drain or residue from the FSRU is discharged overboard. Drip pans are provided under strainers, pumps, etc., requiring occasional examination. A float switch for a high level alarm is provided.

Purifiers, Pumps, Strainers/Filters

See the appendices, Section 13.6 for details for the purifiers, pumps, and strainers/filters.

13.6.2.2 Diesel Oil Storage Tanks

General

The DO storage tanks are made of welded steel construction and are secured to the hull. The capacity of the tanks is defined by their gross volume. Tanks of large capacity are constructed as part of the FSRU's hull structure. The DO storage tanks are provided with necessary fittings such as inlet and outlet connections, drain, air vent, manhole or handhole, overflow, thermometer pocket, level gauge or sounding apparatus, considering the intended use. Level gauge glasses for DO tanks are of a flat and heat resistant type. DO tanks located over the engine room floor are provided with drip pans or oil trays having drain piping where necessary.

Tanks

The DO tank for the EDG is fitted with a manual wire-operated quick closing valve at the outlet of the supply line to the engine. *See* the appendices, Section 13.6 for additional storage tank information.

APPENDICES TO RESOURCE REPORT 13.6

Fuel System Appendix

Appendix 13.6.1: Fuel Gas System

LP BOG fuel gas heater/312383-SAI-DS-116
A/B HP Fuel heater/312383 SAI-DS-121
Utility Flow Diagram fuel gas system/312383-SAI-UFD-104

Appendix 13.6.2: Diesel Oil System

UFS – Diesel supply (DO transfer & purification)/312383-SHI-PFS-100.01-Rev1
UFS – Diesel supply (DO service system)/312383-SHI-PFS-100.02-Rev1

13.7 DESIGN PLANNING

13.7.1 Basis of Design

The overall design planning philosophy for the Broadwater LNG facility is to develop a safe, efficient and reliable facility which minimizes environmental impacts, while still meeting the technical and commercial requirements for the terminal.

The FSRU will be an LNG receiving terminal which will be designed to operate at a nominal annual throughput of 1 billion cubic feet per day (bcfd) with peak send out rates up to 1.25 bcfd. The terminal requires a net storage capacity of 350,000 m^3 of LNG and is designed to deliver natural gas into the existing Iroquois pipeline with one new tie-in pipeline. The LNG will be imported in LNG carriers ranging in size from 125,000 m^3 to 250,000 m^3.

All design and subsequent construction activities will be performed in accordance with the applicable codes and standards, laws and regulations, as described in Sections 13.12 and 13.14. These include but are not limited to the following:

- American Petroleum Institute;
- American Society for Testing & Materials;
- Occupational Safety and Health Administration;
- National Fire Protection Association;
- Ship Classification Society;
- International Gas Code; and
- Safety of Life at Sea.

The design and operation of the Broadwater FSRU is based on the following principles:

- Broadwater (TransCanada and Shell Broadwater Holdings) Health Safety and Environment (HSE) principles;
- Broadwater Sustainable Development principles;
- Reliability and availability;
- Operations, maintenance, and serviceability;
- Avoidance, where possible, of using prototype equipment;
- Following "marine" standards as much as possible to facilitate shipyard construction practice;
- Appropriate codes and standards;
- 24-hr berthing, offloading and send-out operations;
- No unplanned shut-downs; and
- Helicopter and supply boat access.

The FSRU is designed based on an application of three existing and proven technologies.

- **LNG Carrier technology.** This is used for the design and construction of the FSRU hull and its containment system. As of 2004, there were over 170 LNG carriers in operation worldwide, with 20 more scheduled for delivery in 2005.

- **LNG process and regasification experience from onshore terminals**. There are more than 50 onshore LNG import / regasification terminals in operation worldwide with many more planned and/or under construction. There are currently 5 (4 onshore, 1 offshore) terminals in the USA which are actively receiving LNG deliveries, with more terminals in development or construction.

- **Offshore Floating Production Storage and Offloading (FPSO) technology**. Like an FSRU, an FPSO is moored in place to the sea floor. An FPSO is used to produce, treat and store hydrocarbon products, typically oil. About once or twice a week a shuttle carrier offloads the hydrocarbons from the FPSO and brings them to shore. FPSO's have a proven track record of safe operations around the world for more than 25 years. FPSO's operate continuously in some of the most severe weather conditions. Currently, there are some 80 FPSOs in operation in areas such as the North Sea, Africa, Canada, South East Asia, and Brazil.

The FSRU is designed to be constructed in a shipyard that is equipped to construct LNG carriers. A substantive pre-qualification process will be completed prior to the selection of a prime contractor. The prequalification process will at a minimum qualify potential contractors based on their Health, Safety and Environment programs and performance records, Quality Assurance and Quality Control program, past LNG carrier construction experience and financial status.

13.7.2 HSE & Sustainable Development

Health Safety and Environment (HSE) and Sustainable Development (SD) aspects for the project will be managed in line with established codes and standards, international practices, and Broadwater Energy corporate policies.

The project will take a proactive approach to HSE management through:

- Systematic identification and documentation of HSE hazards;
- Development of a thorough understanding of the causes, consequences and impacts of the identified hazards;
- Development and selection of appropriate mitigation to manage the risk of each HSE hazard; and
- HEMP and Hazard Management.

Broadwater's Hazards and Effects Management Process (HEMP) is a systematic approach used to evaluate safety and environmental hazards, their potential consequences and impacts, barriers to control and mitigate, and the assessment of the risk.

Hazard A Hazard is defined as anything that gives rise to the potential to cause harm. Hazards may be categorized as follows:

- **Safety Hazards** that consider acute events and their effects upon people, assets, production, and reputation.
- **Health Hazards** that give rise to acute or long-term chronic health effects.
- **Environmental Hazards** that consider the characteristics of the site-specific operations and their interactions (positive or negative) upon the environment.

Effect Effect is usually an adverse impact on people, the environment, or property, but also includes beneficial impacts to environmental, social, or cultural systems, either directly or indirectly. Typical effects considered include:

- Direct Consequences such as leak rate, fire sizes, gas cloud dispersion, and oil spill movement.
- Impacts associated with an event such as fire / radiation damage or escalation, barrier performance, effects on people and effects on the environment.

Barrier (or HSE Critical Element) Barriers are the existing and proposed hardware and systems that will prevent, control or mitigate the event. Typically barriers include the facility safety and environmental control and mitigation equipment (emergency shutdown system, fire and gas detection system, fire fighting systems, drain collection systems, blowdown system, life saving appliances and escape routes) and procedures (escape, evacuation and rescue; manual fire fighting; oil spill clean up; permit to work system; inspection and maintenance programs).

Each barrier should have a defined performance standard that includes requirements for:

- Functionality
- Availability
- Reliability
- Survivability
- Maintenance
- Inspection and Verification

Broadwater applied this process during the design of the project. The primary aspects of the HEMP process applied during the Resource Report 13 design have been through hazard identification and specification of HSE control philosophies and equipment. Broadwater is committed to applying this process as the design develops.

13.7.2.1 Hazard Identification (HAZID)

During the conceptual design, and Resource Report 13 development, two HAZID workshops were held to identify and mitigate the potentials hazards for the project. Each HAZID consisted of a formal systematic team-based brainstorming process to identify potential areas of hazard, and develop action plans to mitigate or resolve such hazards.

The HSE process was initiated for Broadwater by the Coarse HAZID that was completed on November 4-5 2004. The Coarse HAZID report is presented in Appendix 13.7. From June 8-10, 2005, nearing the later stages of the Resource Report 13 design development, a second detailed HAZID was held to confirm that actions from the Coarse HAZID were completed, or remained logged, and to further identify new hazard items, after completion of a more detailed level of design. The HAZID reports are provided in Appendix 13.7.

The main categories of hazards affecting the terminal, as identified during the HAZID, are:

- Storage and processing of LNG and natural gas;
- LNG Carrier approach and unloading operations;
- Transportation of personnel to and from the installation; and
- External environmental influences.

The potential hydrocarbon release scenarios include:

- LNG and natural gas leaks from the unloading arms, cargo storage tanks and tank domes and process equipment;
- Natural gas leaks from the gas metering, swivel, riser and export systems, fuel gas system and pipe work; and
- Diesel leaks from equipment using diesel.

13.7.2.2 Hazard Management Measures (Control)

Once the hazards were understood, an assessment was completed to ensure that adequate hazard management measures are incorporated into the facility design. The first step in the process is to incorporate good practice into the design by selecting hazard management measures consistent with industry practice and guidance.

During the HEMP process barriers are assessed, performance standards are developed and additional measures are recommended where appropriate.

During the detailed design development of the Broadwater FSRU additional performance requirements will be established for each of the HSE critical systems. The initial list of HSE critical systems that have been established is:

- Facility layout;
- Hydrocarbon containment;
- Fire, gas and spill detection systems;
- LNG spill control, drainage and cold protection;
- Area classification and ignition control;
- Emergency Shutdown (ESD);
- Emergency Shut Down Valves (ESDVs);
- Emergency Depressurization;
- Emergency LNG Liquid Dump;
- Relief, vent and flare system;
- Escape and evacuation systems;
- Temporary Refuge;
- Aids to Navigation;
- External Communication Systems;
- Pipeline ESD Valve; and
- Active fire protection and control systems.

13.7.2.3 HAZOP Analysis

During the detailed design phase, action issues that were logged in the Coarse HAZID and detailed HAZID which have not been completed will be finalized. The action items noted to be completed during detailed design are provided in Appendix 13.7.

During the detailed design phase, Broadwater will complete a Hazard and Operability Review (HAZOP) to further identify both hazards and operability issues. Hazard identification will continue to be the main focus of this review, although operability problems will be identified to the extent that they have the potential to lead to process hazards resulting in an environmental violation or having a negative impact on safety. Broadwater remains committed to addressing identified issues that may be identified in the future.

13.7.3 Design Studies

Design studies providing support for the design selections are provided in Appendix 13.7, as follows:

- Boil-off gas calculations to determine the sizing for BOG compressors;
- Flare and vent calculation to determine the flare requirements;
- Calculations to determine the size selection of the nitrogen plant; and
- Line Sizing,

Further design decisions are addressed in Resource Report 10 (Alternatives), Section 10.8 LNG Terminal Equipment / Technology Alternatives.

APPENDICES TO RESOURCE REPORT 13.7

Coarse HAZID report
HAZID report
Boil Off Gas Calculations 312383-SAI-CAL-102
Flare and Vent Calculations 312383-Sai-CAL-105
N_2 Calculations 312383-SHI-REP-101
Line Sizing 312383-SAI-CAL-103

13.8 MAJOR EQUIPMENT

13.8.1 Process

13.8.1.1 Design Rules & Regulations Summary

The applicable codes and standards are:

- API RP 14C – Recommended Practice for Analysis, Design, Installation, and Testing of Basis Surface Safety Systems for Offshore Production Platforms;
- API RP 520 – Sizing, Selection, and Installation of Pressure-Relieving Devices in Refiners;
- API RP 521 – Guide for Pressure-Relieving and Depressing Systems;
- NFPA59A (as applicable);
- API RP 610 – Centrifugal Pumps for Petroleum Heavy Duty Chemical and Gas Industry Services;
- API RP 617 – Axial and Centrifugal Compressors and Expanders – Compressors for Petroleum, Chemical and Gas Industry Services;
- API RP 618 – Reciprocating Compressors for Petroleum, Chemical and Gas Industry Services;
- American Society of Mechanical Engineers (ASME) Section VIII – Boiler and Pressure Vessel Code: Section VIII Division 1 – Rules for the Construction of Pressure Vessels;
- API RP 660 – Shell and Tube Heat Exchangers for General Refinery Services;
- TEMA Standards for Shell & Tube Heat Exchangers; and
- ASME B73.1 – Pumps.

Other design rules used for the sizing of the equipment are indicated below:

- Maximum LNG carrier boil-off rate is 0.15 vol %/day, based on pure methane;
- The design of the terminal vapor handling facilities is based on an LNG saturation pressure of 170 mbarg for the LNG carrier. Above this saturation pressure, LNG loading is undertaken at a reduced rate to prevent flaring;
- The heat input of the LNG carrier's cargo pumps during loading is assumed based on a pump efficiency of 75%. This shall be checked during detailed design depending on the final loading calculations and the LNG pump curve;
- The vapor return flow rate to the LNG carrier is as required to load at the maximum rate of 15,000 m3/h;
- Vapor return from the FSRU to the LNG carrier takes place by differential pressure. A pressure differential of at least 55 mbarg is maintained to suppress flashing in the storage tanks and drive the vapor back to the LNG carrier without a blower;
- The discharge head used for LNG carrier's cargo pumps is 135 m;

13.8.1.2 Major Process Equipment

The following text provides descriptions of the major process components. The corresponding equipment is shown on the process flow diagrams and the piping and instrumentation diagrams, equipment lists, and pump details in the appendices, Section 13.8.

The major process components are:

- Loading Arms;
- In-tank LNG Pumps;
- Boil-off and Vapor Handling Systems;
- BOG Compressors;
- N_2 Injection for Gas Heating Value Control;
- Recondenser;
- LNG HP Pumps;
- Vaporizers;
- Superheating for Send-out Gas;
- Metering, Odorization and Gas Send-out;
- Vent and Flare Systems; and
- Heating Medium System.

In addition, other features of the FSRU are discussed below, including:

- Utilities (including Power Generation, a Compressed Air System, and IGG);
- Nitrogen Supply and Distribution;
- Freshwater System;
- Distilled and Domestic Systems;
- Cooling Water System;
- Sewage System;
- Machinery Space Ventilation;
- Wastewater Treatment; and
- Miscellaneous Tanks.

13.8.1.3 Loading Arms

Two LNG full-bore 16" conventional loading arms, one vapor return arm, plus a spare vapor/liquid arm are provided on the loading platform.

13.8.1.4 In-Tank LNG Pumps

Eight in-tank LNG pumps are required, each with a capacity of 830 m^3/h LNG. One pump is installed in each tank. A spare pump will be stored at the warehouse on the FSRU or at the onshore support base. The in-tank LNG pump is sized based on operating three pumps during peak send out. The pumps are provided with kickback lines to protect against minimum flow.

13.8.1.5 Boil-off and Vapor Handling Systems

The basis for the design of the BOG handling systems is that the vapor return to the carrier is at -150°C. The steady state return temperature will be confirmed in the next project phase (specification phase).

13.8.1.6 BOG Compressors

Three reciprocating BOG compressors and one centrifugal BOG compressor are installed. Each reciprocating compressor is sized for 33% of the maximum expected BOG rate and the centrifugal compressor is sized for 50% of the maximum expected BOG rate.

13.8.1.7 N_2 Injection for Gas Heating Value Control

Nitrogen is injected upstream of the recondenser to meet the heating value and flame stability requirements (Wobbe Index) of the send-out gas to meet downstream requirements. Nitrogen up to a maximum of 4% by volume will be injected; this is necessary due to the expected composition range of LNG arriving at the FSRU. The nitrogen injection rate is proportional to the send-out rate.

13.8.1.8 Recondenser

The recondenser operates at a pressure of 8 barg at the liquid outlet of the facility. The facility is designed to condense the normal BOG from the tanks, the injected nitrogen and the additional BOG generated during loading. Sufficient LNG is pumped to the recondenser to condense the BOG and maintain a condensate temperature 5°C below the saturation temperature of the outlet LNG. This ensures a safety margin since the LNG exiting the facility is sub-cooled. The HP send out pump kickback header is piped back to the recondenser. The recondenser is provided with a depressurization valve and manual drain back to the LNG storage tanks and a process/pressure safety valve (PSV).

13.8.1.9 LNG HP pumps

HP pumps are vertical submerged motor multistage centrifugal type pumps. All HP pumps are identical and are fed from a common HP pump suction header. Each of the pumps feeds one vaporizer. The design pressure of the pump can and suction piping is equal to the design pressure of the LP pump discharge piping system. The discharge lines have check valves to prevent back-flow through the pumps and protect against over-pressure of equipment upstream of the pump, including the recondenser.

13.8.1.10 Vaporizers

Each vaporizer is in line with a corresponding HP send-out pump. There is no header between the HP send-out pumps and the vaporizers. All vaporizers are of the STV type and operate at approximately 105 barg. The exact operating pressure depends on the pump curve of the HP sendout pumps and the operating pressure of the pipeline. Each STV is matched to the capacity of the HP send out pumps, i.e., approximately 365 m3/h of LNG. The heating medium for the STV is 50/50 glycol water supplied at a temperature between 72°C and 85°C. The temperature approach between the gas outlet temperature and the heating medium outlet temperature is 11°C.

13.8.1.11 Superheating for Send-Out Gas

Superheaters are of the printed circuit heat exchanger (PCHE) type and use the higher temperature heating medium stream from the WHRUs. The superheating system is designed to heat gas from 20°C to 62°C at the peak send-out rate. Two 100% units are installed for the base case at peak send-out rate. Gas temperature is controlled using a heating medium bypass control loop.

13.8.1.12 Metering, Odorization, and Gas Send-out

One meter station is provided in the peak send-out case to serve the single send-out pipeline. The metering station consists of three meter runs, using 10" ultrasonic meters with fiscal-accuracy. One spare meter run is provided to facilitate maintenance and calibration of the meters.

Gas odorization is required to satisfy downstream pipeline requirements. The odorant is injected at the inlet header to the meters. Online gas chromatographic analysis of the exported gas is done at the gas header. There is room available for two isocontainers of odorant.

13.8.1.13 Vent and Flare Systems

A flare stack is provided to safely dispose of any emergency hydrocarbon release. No hydrocarbon emissions are expected during normal operation and planned maintenance events.

All process equipment safety valves (except STV PSVs) and depressurization valves are routed to the flare stack for emergency disposal. A flare knock-out (KO) drum is provided to collect potential liquid dropout resulting from liquid carryover or a PSV/depressurizing release.

The tank overpressure relief valves are discharged to the flare system. The flare system design case is based on the relief volume associated with tank roll over. The vented gas from the relief valves on the STVs is then routed to a safe location.

13.8.1.14 Heating Medium System

The main source of heat for the glycol water heating medium (HM) loop is from the process heaters. Each process heater is designed to deliver about 54 MW of heat.

The HM system consists of a 50/50 glycol/water circulation loop that is heated in the process heaters and the WHRUs. The HM from the process heaters and the HM return from the superheaters provide heat to the LNG vaporizers.

The HM from the WHRU provides heat to the LNG superheaters and to the ancillary heating water system through a cross exchanger. The ancillary heating water system is used for cofferdam heating in the hull and for fuel gas heating. An electric resistance water heater is provided as a backup for the cross exchanger during initial start-up or when the HM system is out of service.

The colder HM from the expansion tank extracts heat from the cooling water system through a cross exchanger. The cooling water system is used for cooling requirements of the nitrogen system, the electric power generators, the accommodation and the machinery space equipment. In the event that the HM system is not operating, seawater is used in conjunction with a separate cross exchanger as a backup for the primary cross exchanger for all cooling needs. The seawater system for cooling is not normally operating.

Process heaters are equipped with vertical Selective Catalytic Reduction Units to reduce the NO_x content down to 2.5 parts per million (ppm) or less. Aqueous ammonia is injected in the exhaust gas stream. Volatile organic compounds (VOCs) and CO contents are also reduced to 10 ppm or less by use of special catalysts.

13.8.2 Utilities

13.8.2.1 Design Rules and Regulations Summary

Classification Society

The FSRU, including hull, machinery, equipment and outfitting, will be constructed in accordance with the Class Rules (2003 year edition) and under survey of the Class and is distinguished in register by the symbol of: the ABS, ✠A1 F(LNG)ORS, SH-DLA(S100) Long Island Sound, SFA(40), SHCM, UWILD.

Rules and Regulations

The FSRU will comply with the following rules and regulations:

- International Convention for SOLAS, 1974 with Protocol of 1978, and the amendments of 1981, 1983, 1988, 1989, 1990, 1991, 1992, 1994, 1996, 1998, 2000 (as applicable to FSRU);
- International Convention on Load Lines, 1966 with the Protocol of 1988;
- International Convention for preventing Collisions at Sea, 1972 including amendments of 1981, 1987 and 1989;
- International Convention of the Prevention of Pollution from Ships (MARPOL);
- International Convention on Tonnage Measurement of Ships, 1969;
- International Convention for Telecommunications;
- IGC code;
- IMO resolution A.468(XII), "Code on Noise Levels on board Ships", 1981;

- ISO 6954-2000(E), "Guidelines for measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships;"
- Amendments to the SOLAS Convention concerning Radio Communications, for the Global Maritime Distress and Safety System (GMDSS);
- USCG Safety Standards for Self- Propelled Vessels Carrying Bulk Liquefied Gases as a foreign flag vessel to be intended to call at US ports except Alaskan water and public law "Port and Tanker Safety Act of 1979;"
- Equipment and Arrangement by ILO Convention No. 92, concerning Crew Accommodation on Board Ship; and
- International Labor Organization (ILO) convention 152, Occupational Safety and Health in Dockwork, 1977, as amended in 1979.

13.8.2.2 Power Generation

Main Power Generation

Main power is generated with three GE LM 2500 + DLE Aero-derivative Gas Turbine Generators or equivalent equipment from another manufacturer. Vaporized LNG is used as fuel in the gas turbine during normal operation. One of the gas turbines has black start capability. It has a dual fuel turbine and can operate on gas oil or on NG. This turbine is used during the initial start up of the project and at any other time when a black start situation occurs.

Gas Turbine Generators

The aero-derivative gas turbine is connected to an electric generator. This turbine is a hot end drive, two-shaft gas turbine.

Waste Heat Recovery Unit (WHRU)

A horizontal WHRU is attached at the exhaust end of the gas turbine. Turbine exhaust gas at 520°C to 550°C passes through the CO catalyst to reduce CO to 10 ppm or less and then through an HM (glycol water) tube bundle. A NO_x reduction catalyst SCR is located after the primary heat exchange bundle. There is a second heat exchange bundle downstream of the NO_x reduction catalyst bed. Aqueous ammonia is vaporized in the ammonia dilution skid, atomized and injected in the exhaust gas stream. The NO_x is reduced to between 2.5 and 5 ppm. The second heat exchange tube bundle recovers most the remaining heat in the exhaust gas stream. The exhaust gas is discharged to the atmosphere.

Essential and Emergency Power Generation

Essential and emergency power is supplied by three diesel engine generators (Caterpillar® or equivalent), one of which is the designated emergency generator. The Model 3608, 8 cylinder engines have radiator cooling to reduce dependence on any seawater cooling requirements. Each engine drives a 2.4 MW electric generator. The electric generator rotates at 900 revolutions per minute (rpm) to produce 3 phase, 60 Hz and 60

The total essential and emergency power requirement is approximately 4 MW. Two diesel engine generators can meet the power requirement. The third diesel engine generator is a spare and satisfies the N+1 sparing requirement of the project.

13.8.2.3 Compressed Air System

General

The construction, materials, and accessories of air compressors and air reservoir are in accordance with the relevant manufacturers' standards. The compressed air system comprises a starting air system for essential diesel generator engines and emergency generator engine, a control air system, and a general service air system. Compressed air of 25 bar is used to start the essential diesel generators and EDG engines.

13.8.2.4 Inert Gas Generation

General

The plant is designed to produce inert gas and dry air of a quality compatible with the containment system and equipment. Special arrangement (i.e., non-return deck seal) is made to prevent any return of cargo gas to the inert gas generator room. The inert gas/air dryer (i.e., cooling and dryer unit) is installed in the machinery space.

The system consists of:

- One inert gas generator with seawater washing tower;
- Two blowers, 50% capacity each;
- One fuel oil pump unit;
- One cooling unit;
- Two absorption vessels; and
- One control and alarm panel set.

Inert Gas Piping

The inert gas is supplied to the cargo tanks through the cargo liquid or vapor header via a spool piece. Connection to the duct keel is via a spool piece and a shut off valve. Connection to the ballast line is provided for the ventilation of ballast tanks, via pipeline with a manual valve and a spool piece on deck.

Control and Alarm

The inert gas/dry air plant is started up and stopped from the local control panel and is monitored remotely from the DCS and from the local control panel. The local control panel with mimic diagram showing the principle picture of the inert gas system is located at the scrubber side and also is displayed in the DCS. The mimic graphic with alarms is also displayed on the DCS workstation.

Inert Gas Generator

The inert gas generator has a capacity of 4,500 Nm^3/h of inert gas, which is based on one tank operation of drying, inerting, and aeration within each 20 hours. The inert gas is produced by the stoichiometric combustion of fuel oil and air in a combustion chamber with the combustion air force fed into the combustion chamber by blowers and the oil injected by means of gear pump.
It is anticipated that the inert gas system will be required for storage tank inspection no more than once in every 5 years for each tank.

Combined Scrubber/Burner Unit

The plant does not employ refractory lining.

Blower

There will be two rotary blowers of the electric motor-driven roots type. The motors are fitted with thermistor protection.

DO Pump Unit

The DO pump will be of gear type with electric motor and turn-o-clean or duplex oil filters.

Inert Gas/Air Dryer

The plant is designed to dry the inert gas and air. The dew point of the dry air product is the same as inert gas.

Cooling Unit

The cooling unit consists of a refrigerant gas compressor and freshwater cooled condenser and is built as a common unit with control equipment for automatic operation. The plant is able to cool the flow of inert gas in such a way as to trap the water contained in saturation. The plant is also capable of cooling inert gas to +5°C, relative humidity 100%. The system consists of one compressor, one inert gas cooler and necessary control and safety equipment.

Dryer Unit

The system consists of two dryer vessels, one blower of two bearing type and two air heaters (each 100 % capacity, electric, one working and one stand-by). The two dryer vessels consist of drying towers filled with activated alumina, regenerated automatically by two air heaters. In case one vessel is in drying operation, the second vessel will be regenerated and the regeneration time is about six hours. It is possible to run or regenerate dryers without running inert gas blowers.

13.8.2.5 Nitrogen Supply and Distribution (for Purging and Containment Monitoring)

General

The nitrogen generators, which are separate from and independent of the nitrogen system used for the process calorific value adjustment, provide nitrogen gas to:

- Supply the interbarrier spaces (IBS) and insulation spaces (IS);
- Purge the cargo liquid line, vapor lines, and vent lines;
- Purge the manifolds ends after connection and before disconnection;
- Purge the loading arms; and
- Purge the fuel gas skids.

The nitrogen gas is produced by two nitrogen generation units and stored in a buffer tank at a pressure of 10 bar. The system consists of two nitrogen generators, two air compressors, and one buffer tank for nitrogen gas.

13.8.2.6 Freshwater Systems

General

Fresh water for domestic use, drinking, and general service is stored in freshwater storage tanks (port and starboard) of approximately 230 m^3 capacity that supply freshwater general services throughout the FSRU. Each tank can supplement the other system via normally locked shut valves. Both tanks are normally filled from the freshwater generators.

Fresh water from the freshwater tanks is supplied to the following systems by means of a hydrophore system:

- Freshwater system in machinery space;
- Domestic supply water and drinking water to accommodation;
- Hot water circulating system;
- Water mist system; and
- Freshwater hydrant in the accommodation area.

13.8.2.7 Potable Water

General

Potable water is treated by an approved system before distributing to the hydrophore tank. It then is distributed on demand by a hydrophore system. The water system size is based upon the current manpower projection of a maximum of 60 people. Potable water for utility, the accommodation area, and topsides service are supplied by two pumps, which pressure the hydrophone tank of 2 m^3 capacity. The system supplies water at a rate of 10 m^3/h at 6 bar. One of the pumps is on duty with the other pump on automatic standby.

13.8.2.8 Distilled and Domestic Systems

General

Two freshwater storage tanks are also available for potable water and general use--such as washing down, first aid, fire fighting, and any uses for the process system. The desalination/distillation units consist of two units to produce potable and freshwater from seawater. Water produced by the freshwater generators is piped directly to the water tanks. The freshwater tanks can also be filled from supply boat connections at the accommodation port side. A mineralizer (rehardening filter) is provided at the discharge line of freshwater generator.

Domestic water for utility, topside and accommodation service including laundry, kitchen, cabins, smoking areas, etc., is supplied by two pumps, which pressure the hydrophone tank of 2 m^3 capacity. The system supplies water at a rate of 10 m^3/h at 6 bar. One of the pumps is on duty with the other pump on automatic standby.

Hot freshwater from the calorifier is supplied to all wash-basins, showers, sinks, wash troughs, and washing machines.

13.8.2.9 Cooling Water System

13.8.2.9.1 Freshwater Cooling

General

The centralized freshwater cooling system is applied to the main and auxiliary machinery in the machinery space. For all main and auxiliary equipment, cooling is provided via a central fresh - water cooling system, utilizing plate coolers with a back flushing system. The cooling water system is designed based on 36°C freshwater, 30°C glycol water, and 30°C seawater. Seawater cooling is only a back-up system should the glycol water system not be available.

13.8.2.9.2 Seawater Cooling

General

In order to minimize the quantity of seawater used, the seawater cooling system is provided only as a back-up system for the glycol water system. The seawater supply is through sea suction grids and coarse sea chest filter. The grid is equipped with bars to ensure that large mammals, fish, and divers cannot enter.

The flow at the intake screen has a maximum velocity of 0.15 m/s. Intakes are to be fitted on each side of the FSRU hull with a crossover pipe between the suctions (the pipe will be fitted with central isolating valve to enable all seawater systems to be provided from either the port or starboard sides). Two low intakes are provided on the bottom of the FSRU.

13.8.2.10 Sewage System

General

The sewage system is subject to USCG and New York State Department of Environmental Conservation (NYSDEC) Regulations.

The NYSDEC sewage related regulations are set forth in table 8.1 and USCG sewage regulations are set forth in table 8.2 below.

To comply with the regulations, a membrane bioreactor (MBR) is intended for the treatment of sewage. This option represents the most modern and effective technology available.

The specifications in Tables 8-1 and 8-2 and experience from MBR manufacturers compare well with NYSDEC regulations, but are subject to discussion and approval by the NYSDEC. Should approval not be gained from NYSDEC, then all sewage will be retained on board the FSRU for removal and disposal at a suitable shore facility.

The MBR size required for a maximum of 60 persons is as follows:

- Max influent 19,500 kg (mostly clean water); and
- Max organic load (BOD) 11.3 kg/day.

The sewage from water closets in the accommodation area is collected into the sewage treatment plant in the machinery space by the vacuum unit. The sewage from the hospital bathroom and wash basin is led to the sewage treatment plant through a gravity pipeline. The residual sewage in the sewage treatment plant is retained and discharged to the ship connection by the sewage discharge pump. The discharge outlet of treated water from the plant is located near the ballast water line. A storm valve is provided at side shell outlet for the drainage main.

Parameter	Water Classes	Standard
Turbidity	SA	No increase that will cause a substantial visible contrast to natural conditions
Suspended colloidal and settleable solids	SA	None from sewage, industrial wastes or other wastes that will cause deposition or impair the waters for their best usages
Oil and floating substances	SA	No residue attributable to sewage, industrial wastes or other wastes or visible oil film nor globules of grease
pH	SA	The normal range shall not be extended by more than one-tenth (0.1) of a pH unit
Dissolved oxygen	SA	Shall not be less than 5.0 mg/L at any time
Dissolved solids	SA	Shall not exceed 200 mg/L. Shall be kept as low as practicable to maintain the best usage of waters but in no case shall exceed 500 mg/L
Total Coliform (number per 100 ml)	SA	The median most probable number value in any series of representative samples shall not be in excess of 70

Table 8-1: **NYSDEC sewage related water quality regulations**

Parameter	Standard
"Gray Water"	Defined as shower/sink drain water, there are no general federal restrictions regarding "gray water" discharge. Unless a sensitive area has been identified as a no-discharge
Sewage	0-3 miles – discharge only after treatment of processing is completed through a Coast Guard approved marine sanitation device (Type I or Type II) Type III untreated sewage discharge is not permitted in Long Island Sound. Beyond 3 miles – sewage discharge is permitted

Table 8-2: **USCG sewage regulations**

13.8.2.11 Machinery Space Ventilation

General

Ventilation of the machinery space is done by the machinery space ventilation fans. Fresh air is supplied through ducts to the machinery space. Excess air from the machinery space is discharged to the atmosphere through the opening at the front side of the accommodation area. The ventilation system is designed to keep slight positive pressure within the machinery spaces.

13.8.2.12 Wastewater Treatment

Deck Drains and Scupper

Rain water drains from the upper deck are discharged overboard through the scuppers led to the waterline. Deck drains are provided in all enclosed wet spaces in the accommodation area such as the galley, laundry, private toilet/shower and common water closet (WC) and shower in the chemical store.

Wastewater (grey water) from the accommodation area other than the hospital bathroom is collected to the scupper main line and led to either the sewage treatment plant or sewage holding tank. The grey water from the hospital bathroom is separately led to either the sewage treatment plant or sewage holding tank through a gravity pipeline.

Waste pipes, scuppers and drains do not pass through, or under, the deckheads of spaces used for the storage and preparation or food or the storage of electrical equipment.

Weather deck drains in the accommodation area are arranged to drain efficiently on the open deck immediately below through pipes. The accommodation area, stores, and other areas not having a scupper have brass drain plugs to drain to the outside deck.

The scupper for refrigerated provision stores will be fitted with rubber plugs. Galley drains are collected into the sewage treatment plant. Provision stores drains have a separate overboard A mechanical rubber plug is provided for upper deck scupper. Trunk deck drains are arranged to drain efficiently to the upper deck by way of the upper deck scuppers.

Black Water

Flushing water is supplied from the freshwater hydrophore tank to the WC. The black water from WCs is collected into the sewage holding tank or treatment unit in the machinery space by the vacuum unit. The ship transfer connection on the upper deck is provided from the sewage discharge pump in the machinery space.

13.8.2.13 Bilge System

General

The discharge of bilge water is subject to USCG and New York State Department of Environmental Conservations (NYSDEC) regulations. For Long Island Sound, these regulations are set forth in Tables 8.3 and 8.4.

All bilge water will be retained on board for removal and disposal at a suitable shore facility. No bilge water will be discharged to the Sound from the FSRU unless in dire emergency. The emergency bilge overboard is not discussed in detail below based on discussions with NYSDEC that this outfall will not be a permitted discharge since it will only be used for emergency purposes. Any discharge resulting from an emergency release would require response and clean-up as appropriate in conjunction with facility SPCC plans.

Parameter	Water Classes	Standard
Oil and floating substances	SA	No residue attributable to sewage, industrial wastes or other wastes or visible oil film nor globules of grease.

Table 8-3: **NYSDEC bilge related water quality regulations**

Parameter	Standard
Oil	Vessels are permitted to discharge oil wastes only when the vessel is underway and only after processing the oil waste through an oil/water separator resulting in an effluent that is less than 15 parts per million and does not cause a visible sheen.

Table 8-4: **USCG bilge related water quality regulations**

The machinery space has two main bilge tanks, a bilge holding tank and a separate bilge oil tank. The following pumps can be used to pump from the bilge tanks: the machinery space bilge pump, the bilge water separator pump, and the sludge pump.

The separated bilge oil tank can take oily water from the sludge pump coaming, machinery space bilge tank as well as the diesel oil service tank drain. The tank is normally emptied by the sludge pump to a supply boat having an approved onshore reclamation/disposal facility.

The bilge water holding tank accepts bilge from the sewage and STP drain, sludge pump outlet and bilge water separator. The separator bilge pump is normally used to empty the bilge holding tank, to transfer bilge water in the bilge well to the bilge holding tank. A limit switch is fitted for auto stop of the bilge water separator pump as the bilge holding tank level drops. All other scupper drains from the various flats and from various machinery save-alls are drained to the bilge water holding tank for disposal.

All tanks are fitted with high level alarms.

There are three main bilge wells in the machinery space, all linked to a suction ring again linked to bilge pumps. All machinery space bilge wells are equipped with high level switches for alarm generation. The separator bilge pump can take suction from bilge holding tank or from the seawater crossover line.

The machinery space bilge pump is an electrically-driven reciprocating pump, which can take suction from the main suction ring or from the bilge water holding tank. The bilge water is discharged either to the holding tank or to the supply boat via the ship connection. Limit switches on the midship bilge wells enable the pump to be started and stopped automatically. A "long run" alarm is generated by software if the ER bilge pump runs continuously for an extended period.

The sludge pump is an electrically-driven rotary pump that can take suction from the separated bilge oil tank. Sludge is discharged to the supply boat via the ship connection.

13.8.2.14 Equipment Cooling

For all main and ancillary equipment of utilities, cooling is provided from the central freshwater cooling system, utilizing plate coolers with a back flushing system. The cooling medium for the central freshwater cooling system is provided by the main glycol heating/cooling system.

13.8.2.15 Miscellaneous Tanks

General

The tanks are generally made of welded steel construction and are well secured to the hull. The described capacity of tanks is defined by their gross volume. Tanks of large capacity are constructed as part of the FSRU's hull structure. The tank is provided with necessary fittings such as inlet and outlet connections, drain, air vent, manhole or handhole, overflow, thermometer pocket, level gauge or sounding apparatus, etc., considering the intended use. Level gauge glasses for oil tanks are flat and heat resistant. Oil tanks located over the machinery space floor are provided with drip pans or oil trays having drain piping where necessary.

APPENDICES TO RESOURCE REPORT 13.8

Major Equipment Appendix

Appendix 13.8.1. Flow Schematics

Process Flow Diagrams

- PFD Unloading area/312383-SAI-PFD-101
- PFD LNG storage 7 in-tank pumps/312383-SAI-PFD-102
- PFD BOG compressors/312383-SAI-PFD-103
- PFD Recondenser/312383-SAI-PFD-104
- PFD HP send-out pumps/312383-SAI-PFD-105
- PFD STVs/312383-SAI-PFD-106
- PFD Superheaters/312383-SAI-PFD-107
- PFD Nitrogen generation/312383-SAI-PFD-108
- PFD Metering area/312383-SAI-PFD-109
- PFD Flare & Vent/312383-SAI-PFD-110

Process Safeguarding Flow Schemes & SAFE Charts

- Process Safeguarding Flow Scheme N2 Plant /312383-SAI-PSFS-108 Process Safeguarding Flow Scheme LNG H.P pump/312383-SAI-PSFS-105 Process Safeguarding Flow Scheme superheaters/312383-SAI-PSFS-107
- Process Safeguarding Flow Scheme metering area/312383-SAI-PSFS-109
- Process Safeguarding Flow Scheme Flare/vent/312383-SAI-PSFS-110
- SAFE Chart platform indentification/312383-SAI-REP-103
- Process Safeguarding Flow Scheme recondenser/312383-SAI-PSFS-104
- LNG storage tank & LNG in-tank pump/312383-SAI-PSFS-102
- Process Safeguarding Flow Scheme BOG compressor/312383-SAI-PSFS- 103
- Process Safeguarding Flow Scheme STVs/312383-SAI-PSFS-106
- Process Safeguarding Flow Scheme Unloading Area/312383-SAI-PSFS-101

Utility Flow Diagrams (Hull)

- Detailed layout of drainage/effluent system (D.O/L.O drain)/312383-SHI-PFS-101.01-Rev1
- Detailed layout of drainage/effluent system (Bilge)/312383-SHI-PFS-101.02-Rev1
- Utility flow scheme (UFS) instrument air/312383-SHI-PFS-102.01-Rev1
- UFS fresh/potable water system/312383-SHI-PFS-104.01-Rev1
- UFS drainage 7 sanitary waste systems/312383-SHI-PFS-105.01-Rev1
- UFS cooling water system (freshwater/seawater)/312383-SHI-PFS-121.01-Rev1

Utility Flow Diagrams (Topsides)

Utility flow diagram heating medium system/312383-SAI-UFD-101

Utility flow diagram cooling water system seawater/heating medium system/312383-SHI-UFD-102

Utility flow diagram heating water system/312383-SAI-UFD103

Utility flow diagram fuel gas system/312383-SAI-UFD-104

Utility flow diagram cooling water system/312383-SAI-UFD-105

Appendix 13.8.2. Equipment List

Equipment list/312383-SAI-LI-101

Appendix 13.8.3. Equipment Description

Process Data Sheets and Specifications

BOG Compressors

Process Data Sheet BOG compressor/312383-SAI-DS-115

BOG compressor suction drum/312383-SAI-DS-112

A/B/C BOG compressors /312383-SAI-DS-104

BOG superheater/312383-SAI-DS-111

Chlorination Unit

Chlorination unit/312383-SHI-SP-101

Fuel Gas Heaters

LP BOG fuel gas heater shell & tube heater exchanger: PDS/312383-SAI-DS-116

A/B HP fuel gas heater shell & tube heater exchanger: PDS/312383-SAI-DS-121

Heating Medium Trim Coolers

A-F trim cooler, air-cooled heat exchangers: PDS/312383-SAI-DS-119

Heating Medium surge Tank

Glycol water expansion tank general data/312383-SAI-DS-108

H-P Send-Out Pumps

HP sendout pumps, centrifugal pump: PDS/312383-SAI-DS-103

In-Tank Pumps

P-1001-A – P-1008-A in-tank pumps, centrifugal pump: PDS/312383-SAI-DS-110

Loading Arms

Loading arm: PDS/312383-SAI-DS-114

LNG drain vessel, general data/312383-SAI-DS-117

Drain vessel in-tank pump, centrifugal pump: PDS/312383-SAI-DS-120

Process Heaters

F-2201-A-E Process heater:PDS/312383-SAI-DS-106

Recondenser

V-1205 Recondenser/312383-SAI-DS-101

STVs

E-1301 A/H Vaporizers/312383-SAI-DS-102
Spray Pumps
P-1001 B to P-1008B Spray pumps, centrifugal pump/312383-SAI-DS-118
Superheaters
E-1302 A/B Superheater, printed circuit heat exchanger: PDS/312383-SAI-DS-105
Vendor Information
All principal process equipment, plus detailed generators and cranes

Appendix 13.8.4. Equipment Layout
FSRU Section Views

Topsides section view-Aft area/312383-SAI-DWG-403.01
Topsides section view-Midship area/312383-SAI-DWG-403.02
Topsides section view-Fore area/312383-SAI-DWG-403.03
General Arrangement (Hull)
Plant utility layout located inside the hull (elevation)/312383-SHI-DWG-401.01
Plant utility layout located inside the hull (double bottom/floor)/312383-SHI-DWG-401.02
Plant utility layout located inside the hull (3rd deck)/312383-SHI-DWG-401.03
Plant utility layout located inside the hull (2nd deck/upper deck)/312383-SHI-DWG-401.04
Plant utility layout located inside the hull (section)/312383-SHI-DWG-401.05
FSRU Drawing: Typical arrangement for sea water suction & overboard/312383-SHI-DWG-412.01

General Arrangement (Topsides)

Detailed layout of drainage/effluent system (D.O/L.O drain)/312383-SHI-PFS-101.01
Detailed layout of drainage/effluent system (bilge)/312383-SHI-PFS-101.02
Topsides GA/312383-WSN-DWG-402.01, 1 of 21
Topsides GA/312383-WSN-DWG-402.01, 2 of 21
Topsides GA/312383-WSN-DWG-402.01, 3 of 21
Topsides GA/312383-WSN-DWG-402.01, 4 of 21
Topsides GA/312383-WSN-DWG-402.01, 5 of 21
Topsides GA/312383-WSN-DWG-402.01, 6 of 21
Topsides GA/312383-WSN-DWG-402.01, 7 of 21
Topsides GA/312383-WSN-DWG-402.01, 8 of 21
Topsides GA/312383-WSN-DWG-402.01, 9 of 21
Topsides GA/312383-WSN-DWG-402.01, 10 of 21
Topsides GA/312383-WSN-DWG-402.01, 11 of 21
Topsides GA/312383-WSN-DWG-402.01, 12 of 21
Topsides GA/312383-WSN-DWG-402.01, 13 of 21
Topsides GA/312383-WSN-DWG-402.01, 14 of 21
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13.9 FSRU HULL AND LNG CONTAINMENT

13.9.1 FSRU Hull

13.9.1.1 Design Rules and Regulations Summary

Classification Society

The FSRU, including hull, machinery, equipment and outfitting, will be constructed in accordance with the ABS rules (2004 year edition) of the Class and will be constructed under survey of the Class and is distinguished in register by the symbol of:

American Bureau of Shipping
✠A1 F(LNG)ORS, SH-DLA(S100) Long Island Sound, SFA(30), SHCM, UWILD

Rules and Regulations

The FSRU will be constructed with the following rules and regulations:

- International Convention for SOLAS, 1974 with Protocol of 1978, and the amendments up to 2003 (as applicable to FSRU);
- International Convention on Load Lines, 1966, with the Protocol of 1988;
- International Convention for preventing Collisions at Sea, 1972, including amendments of 1981, 1987, 1989 and 1993;
- MARPOL, 1973 (Annexes I, IV, V and VI (Regulation 12,13, 14 and 16) with Protocol of 1978 and the amendments up to 2003;
- International Convention on Tonnage Measurement of Ships, 1969;
- International Telecommunications Union (ITU) Radio Regulations, 1982;
- IGC Code;
- IMO resolution A.468(XII), "Code on Noise Levels Onboard Ships," 1981;
- ISO 6954-1984(E), "Guidelines for the Overall Evaluation of Vibration in Merchant Ship";
- Amendments to the SOLAS Convention concerning Radio Communications, for the GMDSS;
- USCG Safety Standards for Self-Propelled Vessels Carrying Bulk Liquefied Gases as a foreign flag vessel to be intended to call at US ports except Alaskan water and public law "Port and Tanker Safety Act of 1979";
- Equipment and Arrangement by ILO Convention No.92, concerning Crew Accommodation on Board Ship;
- ILO convention 152, Occupational Safety and Health in Dockwork, 1977, as amended in 1979;
- Oil Companies International Marine Forum (OCIMF) Recommendations on Equipment for the Towing of Disabled Tankers;

- OCIMF Recommendations for Standardization of Manifolds for Refrigerated Liquefied Gas Carriers;
- OCIMF Guidelines and Recommendations for the Safe Mooring of Large Ships at Pier and Sea Islands (except special conditions of the Intended terminal);
- OCIMF Ship to Ship transfer guide (Liquefied gases);
- Society of International Gas Tanker and Terminal Operators (SIGTTO) "Recommendations and Guidelines for Linked Ship/Shore Emergency Shutdown of Liquefied Gas Cargo Transfer," 1997; and
- ISO 8309-1991 Refrigerated light hydrocarbon fluids-measurement of liquid levels in tanks containing liquefied gases-electrical capacitance gauges.

13.9.1.2 General Hull Description

The unit is a non-propelled FSRU with an LNG net storage capacity of 350,000 m^3. The cargo containment system will be of the Gaz Transport Et Technigaz (GTT) Mark III type or equivalent NO96 system. The cargo area consists of eight center cargo tanks and nine pairs of water ballast tanks. The hull has an overall length of 366 m (1200 feet) and a beam (width) of 60 m (197 feet). Its depth is 27 m and operates at a summer draught of 13 m. Further hull general and dimensional details are set forth in the appendices, Section 13.9.

The regasification plant is designed and installed for regasifying LNG stored in the FSRU cargo tanks to enable NG to be piped ashore. LNG regasification process equipment is located on the deck of the FSRU. The LNG transfer system, comprising liquid and vapor loading arms, is fitted on the starboard side of the FSRU at a midship location to allow LNG from the LNG carrier to be pumped to the FSRU.

The accommodation area is provided at the stern of the FSRU for 30 permanent and 30 temporary crew members and is of welded steel construction. Full details of the accommodation structure and fittings can be found in Section 13.18 and its appendix.

A helideck is arranged above the accommodation area and is located for optimum position for helicopter operability.

Tank Configuration

Eight center cargo tanks are arranged in a row and each cargo tank is 3200 mm apart from its adjacent tank separated by a cofferdam. Wing tanks and peak tanks are used as water ballast tanks for control of trim, draft, bending moment, and shear force. The tank configuration is double bottom double side. Two freshwater tanks are arranged in the aft part within the hull below the accommodation area. Two diesel oil tanks are arranged adjacent to the machinery space, each with double side protection by wing ballast tanks.

Tank Surveys

As part of Class surveys, tank entry may be required for a close-up inspection of the containment system several times during the life of the FSRU. For visual inspection, the pump tower will be used to access the cargo tanks. An ammonia test will be used to test for tank leakage instead of visual inspection after the gas trial. An alternative method of inspecting tanks after gas freeing is to use television monitors. Detailed tank survey procedures are drawn up for the FSRU during the detailed engineering phase.

<u>**Structural Design**</u>

Material

Material for hull construction is generally of mild steel and high tensile steel which have been approved by the Class. Steel material including material for casting and forging is of a quality that complies with Class Rules.

The grade of steel plates and stiffeners is decided upon in accordance with Class Rules and the IGC.

Testing

Leak tests and structural strength tests are carried out in accordance with Class Rules. Leakage is checked with air test or equivalent methods approved by the Class and shop coat may be applied in the way of welding line prior to the test. A hydrostatic structural strength test is carried out for the selected tanks in accordance with the requirements of the Class to demonstrate structural adequacy. Weather tight and/or watertight doors, hatches, etc., are tested with a water hose in accordance with Class Rules.

Non-destructive testing (NDT) is carried out in accordance with the requirements of the Class.

Temporary access holes for access to the cargo tanks are 100% ultrasonically tested. The corners and weld start/stop points are X-Ray tested after closing plate fitted. All other closing plates for watertight structure are 100% ultrasonically tested.

Type of Inspection and Extent

The type and extent of inspection depends on the information available from the general routine and preliminary inspection, age of the FSRU, requirements as per the classification, etc., and include permanent means of access to facilitate close up inspection of critical areas. The surveys are grouped into three technical types as described below:

a) General Condition Surveys

These are overall surveys of limited scope and time intended to identify gross structural or corrosion related problems. They involve little or no close-up inspection or thickness determination of internal structure, but give an overall visual impression of the structural integrity and corrosion condition of the tanks inspected.

b) Detailed Condition Surveys

Detailed condition surveys provide a more comprehensive and in-depth inspection of the FSRU. A detailed condition survey of the FSRU's structure would encompass a close-up inspection and thickness measurement of a sufficient number of structural elements to accurately assess the present condition so that a course of action can be formulated.

c) Corrosion Rate Surveys

These are limited in terms of area inspected but are of a more detailed nature, and are based on collecting representative thickness measurements of a number of structural components in various tank environments at regular intervals so that general corrosion rates can be determined for the FSRU. In addition, these may identify local corrosion and/or structural problems for the more limited areas surveyed.

Corrosion Protection

Corrosion protection for the steel hull and systems will comprise a comprehensive marine painting system applied in accordance with the corrosion protection details set forth in the appendices, Section 13.9. The underwater outer hull tin-free self-polishing coating system is designed to provide steel protection for life of more than 25 years without repair or reapplication, in accordance with Tanker Structures Cooperative Forum (TSCF) guidelines.

For all other areas, including but not limited to ballast and other water tanks, internal voids, stores and machinery spaces and the accommodation area, painting systems are selected to provide good protection against corrosion, abrasion and where appropriate, a non-slip surface.

Protection is additionally provided for the hull and its appendages by an Impressed Current Cathodic Protection (ICCP) system. Full corrosion protection measures are set forth in the appendices, Section 13.9.

Ballast system

System Description

The ballast water system is fully segregated from LNG tanks and the fuel systems. There are nine pairs of water ballast tanks and two peak tanks. The water ballast tanks are used to adjust trim and to guard against excessive hogging and sagging stresses on the FSRU hull. The water ballast tanks are used to help with draft level control.

Equipment Description

a) Water Ballast Tank

There are 20 water ballast tanks (including peak tanks) in the FSRU to balance the hull stress and provide extra stability. There is no pump room since the pumps and their associated motors are located in the machinery space aft. The total storage capacity of water ballast tanks, at 100% full, is 184,000 m^3.

Two guide pipes for the retractable main cargo pump and one pipe line form part of the pump column structure. The pump guide pipes are used when lowering the main cargo pump and a spare cargo pump. A spring-loaded foot valve is provided on the bottom of the pump guide pipe.

The main cargo pump, cargo loading line, pipes for level gauging equipment, temperature sensors and other necessary fittings are accommodated within the pump column structure. The material of pump column is generally SUS304L. The lower support of the pump column is fitted to the inner hull in accordance with the GTT's design.

One welded-type liquid dome is arranged at the aft part of each cargo tank and one gas pipe is arranged in the mid-part of each cargo tank.

The size, details, construction, insulation and pipe penetrations are in accordance with GTT's design.

The liquid dome cover and pipe penetration material are stainless steel 316L.

Pipe penetrations through the liquid dome are minimized in compliance with GTT's recommendations and design.

In order to improve the piston effect during some operations, a deflection plate will be provided at the end of the vapor line in the cargo tanks.

13.9.2.6 Pressure and Vacuum Relief Systems

The valves are of a stainless steel pilot-operated diaphragm type with a manual operation device. A test connection is provided on each valve for confirmation of set pressure. Valves are tested at the shop and tested onboard to confirm the set pressure before a cold test using test kit.

Cargo Tanks

Each cargo tank is fitted with two safety relief valves sized in accordance with IMO requirements and Class Rules. Relief valves on each tank are discharged to the flare tower.

IBSs and ISs

Each IBS and IS is protected against overpressure by two safety relief valves. The pressure in the IBS and IS is normally kept below the vapor pressure in the cargo tanks. The safety relief valves are pilot-operated and are of the fail-safe design. The discharge of IBSs is led to nitrogen masts without connection with the tanks safety valves mast. The discharge of ISs is directly vented on deck.

13.9.2.7 Calibration

An independent surveyor volumetrically calibrates and produces a set of tank tables for each cargo tank, and its attendant custody transfer equipment has its accuracy verified in compliance with the specification required by the customs authorities.

The tank table correlates the volume of the cargo tank using 0.001 cubic meter as the smallest unit with the tank depth using 1 mm as the smallest unit. The tank tables include the correction tables required for accurate gauging and have corrections provided for trim, list, and float gauge off-sets due to shrinkage and specific gravity.

Automatic input of heel and trim is performed by a dedicated approved type instrument. Trim and list gauges are approved by an independent surveyor during a shop test. The tables are then drawn up to permit the use of either the primary or secondary level measurement system. In addition, calibration procedure for the cargo tanks is submitted for approval.

13.9.2.8 Drying, Purge and Cool-down

After one tank inspection, the following procedures are carried out to load LNG into the cargo tank.

Drying and Inerting of Cargo Tanks

After the tanks and pipes have been tested, the tank atmosphere is dried. For this purpose, dry air (dew point: -45°C) is blown into the tanks by means of a drying installation. The operation is stopped when the air bleeding at the tank upper part has a dew point equal to -20°C. Then the inert gas plant is started, the gas quality is checked for dew point and oxygen content. The inert gas is sent to the bottom of the tanks through the filling line and the air/inert gas mixture is vented through the vapor line and flare tower. The operation is stopped when the final oxygen content reaches below 2% by volume and dew point is lower than -40°C.

Cargo Vapor Purging (Gassing up)

Cargo tanks filled with inert gas are purged with cargo vapor which is produced on board from a small quantity of liquid cargo. The liquid is first used to cool down the appropriate pipelines after which liquid cargo is introduced to the LNG vaporizer. A vapor of about +20°C is generated and is led to the cargo tank from the top via vapor connections. The cargo tank inert gas and any entrained cargo vapor are naturally vented through the flare tower. The resultant cargo tank atmosphere CO_2 content is thus reduced to 1% or less by volume.

Cooling Down

When the inert gas has been exhausted, LNG is introduced to the tank through spray nozzles located in the upper part of the tank. The vapor generated is vented through the flare tower (only if necessary) or burnt in the process heaters.

This operation is controlled by temperature readings taken in different points of the tanks which are equipped with temperature sensors. The operation continues until the mean temperature shown by five sensors, excluding the sensor located in the dome, has reached – 130°C.

13.9.2.9 Inspection and Testing Prior to Operation

Quality Control

All of the quality control is based on GTT specifications describing the requirements of quality and control procedures to ensure the reliability and performance of the containment system. Quality control and quality assurance for supplying the materials and prefabrication of insulation panel are carried out in accordance with the approved procedure by GTT, the Class, and Broadwater.

The main features of the system are as follows.

Raw Material

The main materials for the fabrication of the containment system are: stainless steel, rigid cellular foam, plywood, adhesives, load bearing mastic, studs, and nuts.

Components of Prefabrication

The prefabrication of the components includes: primary barrier "membrane," insulating panels, stainless steel corners, top bridge pads and hardwood keys.

Components of Erection

The erection onboard of the above components includes: installation of the insulation, fitting and welding of the membrane.

Cargo Tank Testing

Resistance Test of Stud Bolt

Resistance test of the stud bolt is performed upon completion of welding of stud bolts and before welding of stud bolts (stainless steel or low carbon steel: S10C of Japan Industrial Standard (JIS) G 4051 or equivalent) in the cargo hold. Significant stud bolts are tested in accordance with the approved procedure by the GTT and Broadwater in order to check the hardness of welding.

Tightness Test of Secondary Barrier

A tightness test of the secondary barrier is carried out in accordance with the requirement of the GTT and the Class and to confirm the tightness of secondary barrier before delivery and/or during operation. For the test, the insulation space is vacuumed down to pressure of -53 kPa and the interbarrier space maintained at atmospheric pressure. Time is measured while the vacuum pressure in the insulation space rises from -45 kPa to -30 kPa and normalized figure is calculated to compare with normal value.

Final Test

The following procedures are carried out for final testing and checking for tightness after tank completion:

1) Ammonia test to check the membrane tightness.

This test consists of injecting a mixture of nitrogen and ammonia inside the membrane corrugations after spraying reactive paint on the welded connections of the membrane. The reactive paint is yellow and it becomes violet with contact with ammonia. If any leakage has occurred, a very precise location of the weld defects in the membrane can be easily determined due to the color changing of reactive paint. This test procedure does not rely on any restricted gases such as Freon and yet achieves a very high degree of accuracy.

2) Vacuum test to establish the reference curve of the secondary barrier.

After completion of the whole containment works in the cargo tank (insulation + membrane), a global vacuum (-530 mbar) test is performed. A vacuum is kept in the IS (between the secondary barrier and the hull). The rise of pressure is measured. The vacuum curves are prepared by the results of this test and also used as the reference for checking of the secondary barrier until all work is completed in the cargo tanks.

3) Strength test to confirm integrity.

A vacuum in the IS of 800 mbar is carried out from final fitting operation (pipe tower installation, dome cover, etc.) but prior to removal of the scaffolding.

13.9.2.10 Monitoring, Inspection and Maintenance During Operation

During each cargo operation, the condition of the cargo containment and handling system are controlled automatically or remotely and continuously monitored from the CCR, and various safety protections are provided to keep the system in a safe and reliable state all the time.

The cargo piping arrangement incorporating double block and bleed allows the gas freeing of any one tank for inspection, while the other tanks are still in operation.

The builder of the FSRU will establish the procedure for carrying out the gas freeing operation and for allowing safe access into the cargo tank. In the case of one tank inspection, a necessary amount of liquid for gas filling and cooling down operations must be kept in one of the other tanks. In these operations, air and inert gas may be introduced into the cargo liquid and cargo gas line; therefore, these lines must be purged of these gases before entering normal service. An expansion bellows-type removable piece for all cargo tanks is provided for emergency vent connection.

Only one tank gas freeing and inspection can be carried out during normal operation.

Warming up		+5°C on secondary barrier, excluding evaporation of the unpumpable
Inerting		2% hydrocarbon by volume
Aeration		20% O_2 by volume
Tank inspection		Inspection/repair of the defective equipment within the tank
Drying of cargo tanks		- 20°C dew point
Inerting of cargo tanks		2% O_2 by volume and – 40°C dew point
Cargo Vapor purging		1% CO_2 by volume
Cooling down		-130°C, average temperature of top and bottom of cargo tanks

Table 9-1: Monitoring, Inspection and Maintenance during Operation

Stripping

Before evaporation of the liquid in the cargo tank, the remaining liquid quantity is reduced to a minimum. This is done by aft trimming the FSRU and using the stripping/spray pumps.

Warming up

Liquid cargo left in the tanks is evaporated and then the cargo tank heated until the mean temperature of the primary barrier reaches about +5°C.

The evaporation is done by circulation of boil off vapor via the compressors and heaters to the bottom of the tanks through the filling lines. The vapor delivered to the tanks is heated to max. +80 °C. The excess vapor is either burned in the process heaters or vented to the atmosphere via the flare tower.

Inerting (Gas freeing with inert gas)

To displace the warm vapor in the cargo tanks, dry inert gas from the inert gas plant is sent to the bottom of the tanks through the filling lines and the gas/inert gas mixture is discharged to the flare tower.

The cargo tanks are considered purged when the cargo tanks secondary membranes are about +5°C, and hydrocarbon content is less than 2% by volume.

Aeration

After the inerting procedure, the cargo tanks are air purged. Dry air from the inert gas/dry air plant is discharged to the cargo tanks either at the bottom via the liquid filling lines or at the top via the vapor lines. The displaced gas is vented to the atmosphere through the flare tower. Oxygen content is increased to 20% by volume or more.

13.9.2.11 Sloshing

Tank Natural Periods

The tank natural period of the fluid in the LNG cargo tank is an important parameter in the selection of the tank excitation period. If the tank excitation period is same as that of the tank natural period, the fluid resonance in the cargo tank occurs and causes the sloshing risk. Therefore, the accurate calculation of tank natural period is essential in the sloshing analysis. The natural periods of the tank in the longitudinal and transverse directions, Tx, and Ty, have been calculated by the sloshing formula from ABS SafeHull LNG and the results are set forth in the appendices, Section 13.9.

13.9.2.12 Spill Protection/ Fire Exposure/ Blast

The cargo containment is provided with a double barrier to prevent low temperatures in the steel structure in case of LNG leakage. Heating is provided in the cofferdams between the cargo tanks to keep the temperature above the specified minimum (+5°C), and adequate redundancy is also provided.

The small drip pans of stainless steel are provided under all flange connections in liquid cargo lines to avoid direct contact of LNG with the steel.

APPENDICES TO RESOURCE REPORT 13.9

FSRU Hull and LNG Containment Appendix

Appendix 13.9.1. Hull

- Midship Section (Ordinary Section)/312383-SHI-DWG-301 (1 –15)
- Preliminary lines plan/312383-SHI-DWG-302
- Distribution of special grade/quality steel in tank boundaries/312383-SHI-DWG-313
- Trim & stability calculation/312383-SHI-REP-200
- Damage stability calculation/312383-SHI-REP-201
- Construction erection sequence drawing/method description/312383-SHI-REP-901
- Hull-general arrangement drawing (Incl. plan view, side view)/312383-SHI-DWG-300

Appendix 13.9.2. LNG Containment

- Schematic layer drawing of containment system/312383-SHI-DWG-305
- Insulation details/312383-SHI-DWG-306
- Insulation panel distribution/312383-SHI-DWG-307
- Primary & secondary barrier details/312383-SHI-DWG-309
- FSRU drawing: pumps/tower/connections arrangement/312383-SHI-DWG-310.01
- Cofferdam heating system/312383-SHI-DWG-311
- Containment insulation details/312383-SHI-DWG-312
- FSRU: drawing: dome arrangement (liquid)/312383-SHI-DWG-403.01
- FSRU: drawing: dome arrangement (gas)/312383-SHI-DWG-403.01
- Containment system general arrangement/312383-SHI-DWG-303
- Cargo containment system various relevant details/312383-SHI-DWG-304
- Insulation installation details/312383-SHI-DWG-308
- Membrane type comparison MARK III vs No. 96/312383-SHI-REP-903
- Broadwater FSRU Containment System – 31283 – SHI-SP-300
- About SHI Slosh
- SHI Slosh procedure
- Wave select procedure

Appendix 13.9.3. Hull System

- Trunk deck layout (plan)/312383-SHI-DWG-409.01
- Abbreviation for ships PFS/312383-SHI-PFS-107.01
- IBS/IS N_2 pressurization system (typical), IBS and IS piping arrangement on liquid dome/312383-SHI-PFS-110.01
- IBS/IS N_2 pressurization system (typical), IBS and IS piping arrangement on gas dome/312383-SHI-PFS-111.01
- Cofferdam temperature sensors (typical)/312383-SHI-PFS-115.01
- Secondary barrier temperature sensors (typical)/312383-SHI-PFS-116.01
- Trunk deck layout (typical section)/312383-SHI-DWG-410.01

Dome pipe sizing loading/unloading/venting/312383-SHI-PFS-106.01
Cargo piping on tank dome (typical)/312383-SHI-PFS-108.01

IBS/IS N_2 pressurization system (typical)/312383-SHI-PFS-109.01
Cargo tank pressure (typical)/312383-SHI-PFS-112.01
Cargo tank level (typical)/312383-SHI-PFS-113.01
Cargo tank temperature (typical)/312383-SHI-PFS-114.01

Appendix 13.9.4. Ballast System
Ballast system/312383-SHI-PFS-122.01

13.10 PIPING AND INSTRUMENTATION

13.10.1 Piping and Instrumentation Drawings

Piping and Instrumentation Diagrams (P&IDs) are included in the appendices, Section 13.10.1. The Valves Summary Drawing is included in appendix Section 13.10.2. Pipeline Layout Drawings are included in appendix Section 13.10.3. The FSRU Control System Drawing is included in the appendices, Section 13.10.4. Additional details regarding piping and instrumentation are set forth in the appendices, Section 13.10.

13.10.2 Piping

13.10.2.1 Design Rules and Regulations Summary

LP cryogenic piping is designed according to shipyard practices for LNG carriers in order to avoid any step outs from the successful experience of marine LP cryogenic systems. The loading piping network is also as per shipyard practices from the loading arms to the liquid domes. HP cryogenic piping is designed according to ASME and NFPA 59A.

Piping Design Summary

All process cryogenic piping and valves are manufactured and tested according to ASME B31.3 and B16.34, respectively. Cryogenic and utility piping and valve systems are supported, routed, and segregated on pipe-racks according to Class Rules. All valves are accessible and easy to operate.

LP cryogenic piping is designed according to shipyard practices for LNG carriers in order to avoid any step-outs from the successful experience of marine LP cryogenic systems. This includes the cargo loading system from the loading arms to the liquid domes.

The regasification process and HP piping is designed according to ASME and NFPA 59A rules. LNG piping and valve insulation is of prefabricated polyisocyanurate or polyurethane foam as appropriate and includes primary and secondary vapor barriers and a watertight jacket and banding for support.

Deck utility piping systems of various materials such as stainless steel, carbon steel, galvanized steel, and aluminum brass are all manufactured and installed according to Class Rules. Full piping and valve details are set forth in the appendices, Section 13.10.

13.10.3 FSRU Instrumentation

13.10.3.1 Design Rules & Regulations Summary

The FSRU instrumentation will be designed in conformance with the following rules and regulations:

- International Electric Convention (IEC) 60092 and the IEC series of guidelines documents;
- AGA 9 – Measurement of Gas by Multipath Ultrasonic Meters - XQ9801;
- API RP 14FZ – Design & Installation of Electrical Systems for Offshore Fixed and Floating Petroleum Facilities for Unclassified and Class 1, Zone 0, Zone 1 and Zone 2 Locations;
- API 14.1 – Manual of Petroleum Measurement Standards Chapter 14, Section 1 – Collecting and Handling of Natural Gas Samples for Custody Transfer;
- API 14.5 – Manual of Petroleum Measurement Standards Chapter 14, Section 5 – Calculation of Gross Heating Value, Relative Density and Compressibility Factor for Natural Gas Mixtures from Compositional Analysis;
- API 14C – Surface Safety Systems for Offshore Production Facilities;
- American National Standards Institute (ANSI)/ISA 84.00.01 – Safety Instrumented Systems;
- CFR Section 30, 250, Subpart H, Oil and Gas Production Safety Systems;
- 46 CFR Part 107 through 11.3.3.2;
- IEC 61511 and IEC 61508– Safety Instrumented Systems;
- UL 864 Fire Detection Systems;
- IMO GMDSS;
- IMOA 167; and
- ITU (International Telecommunication Codes) Recommendations (and others as applicable) as follows:
- Q.23: Technical features of push-button telephone sets;
- Q.503: Digital transit exchanges in integrated digital networks and mixed analog digital networks: Connections, signaling, control, call handling and ancillary functions;
- Q.504: Digital transit exchanges in integrated digital networks and mixed analog digital networks: Performance and availability design objectives;
- Q.920: ISDN user-network interface data link layer – General aspects;
- Q.921: ISDN user-network interface – Data link layer specification;
- Q.922: ISDN data link layer specification for frame mode bearer services;
- Q.930: ISDN user-network interface layer 3 – General aspects;
- Q.931: ISDN user-network interface layer 3 specification for basic call control;
- Q.932: Digital subscriber signaling system No. 1 – Generic procedures for the control of ISDN supplementary services;
- G.703: Physical/electrical characteristics of hierarchical digital interfaces;
- G.704: Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels;
- G.705: Characteristics of plesiochronous digital hierarchy (PDH) equipment functional blocks;
- G.733: Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s; and

- G.734 (11/88) Characteristics of synchronous digital multiplex equipment operating at 1544 kbit/s.

General

The DCS and ESD System are discussed in Section 13.3 of this report and in the appendices, Section 13.3.

Instrumentation and control systems will be designed to be safe and usable under both normal and abnormal operating conditions and will support operational requirements for availability, reliability and maintainability of the plant.

All process plant and utilities required for normal operation are controlled from a permanently manned CCR located within the accommodation area.

DCS regulatory control normally maintains process variables within limits and enables process optimization under operator supervision. This includes the loading of LNG, tank management, regasification, gas treatment and export, as well as ballasting and other such ancillary services. Control and monitoring of the yoke, turret and riser systems are also included in the DCS.

The DCS is supplemented by independent safety systems to detect potentially hazardous conditions and protect personnel, the FSRU and the surrounding environment.

An independent ESD is provided to bring the plant to a safe state in the event of escalation. A comprehensive ESD philosophy is developed, including LNG run-down and gas blow-down as applicable. This philosophy takes account of the need to coordinate ESD actions with those of the LNG carrier during loading and the pipeline facilities downstream of the Sub Sea Isolation Valve (SSIV).

An independent FGS is provided to initiate alarms at appropriate locations throughout the FSRU and initiate remedial actions via the IPS and ESD as appropriate. An F & G philosophy is developed. The FGS comprehensively covers the FSRU, including accommodation area, machinery spaces, equipment rooms and enclosures, process areas, etc., and makes use of appropriate sensing techniques to detect products of fire and natural gas quickly and effectively.

Systems are provided for the monitoring of quantity and quality of LNG received through the loading arms and natural gas exported via the riser(s). An integrated custody transfer system (CTS) is provided to account for LNG received, retained and regasified for export. The CTS is independent of the DCS, but is interfaced to the DCS in line with the automation and control philosophy.

Instrumentation and control systems are designed to allow for safe and effective testing and maintenance without adverse impact on the availability of plant. Facilities are provided on board for routine test and maintenance.

See also Section 13.3, and the "Philosophy for Alarm Management, F&G and ESD Systems" Report, 312383-SAI-SP-605, in the appendices, Section 13.3.

Gas Chromatograph

An inline gas chromatograph also will be used to monitor the incoming LNG and other streams.

Telecommunications Systems

A system of telecommunications that provides for voice and data communication for both normal and emergency operation of the FSRU will be used.

APPENDICES TO RESOURCE REPORT 13.10

Piping and Instrumentation Appendix

Appendix 13.10.1. Piping and Instrumentation Diagrams (P&IDs)

- PID symbols & legend, sheet 1/312383-SAI-PID-001
- PID symbols & legend, sheet 1/312383-SAI-PID-001A
- PID symbols & legend, sheet 2/312383-SAI-PID-002
- PID symbols & legend, sheet 3/312383-SAI-PID-003
- PID symbols & legend, sheet 4/312383-SAI-PID-004
- PID loading area/312383-SAI-PID-101
- P&IDs LNG storage tank & in-tank pump/312383-SAI-PID-102
- PID BOG compressor/312383-SAI-PID-103
- PID recondenser/312383-SAI-PID-104
- PID HP send-out pumps/312383-SAI-PID-105
- PID STV/312383-SAI-PID-106
- PID superheater/312383-SAI-PID-107
- PID nitrogen generation/312383-SAI-PID-108
- PID metering area/312383-SAI-PID-109
- PID flare & vent/312383-SAI-PID-110
- Topsides drawing Index
- Piping Specifications

Appendix 13.10.2. Valve Summary

- Relief valve summary/312383-SAI-LI-501-02
- Shutdown & blowdown valves summary/312383-SAI-LI-503-01

Appendix 13.10.3. Piping Layout Drawings

- Process deck piping layout/312383-SAI-DWG-405.01
- Pipe rack cross section/312383-SAI-DWG-406.01
- Utility piping above deck/312383-SAI-DWG0411.01

Appendix 13.10.4. FSRU Control System

- Instrumentation vendors list/312383-SAI-LI-502
- Instrumentation control and telecoms description/312383-SAI-REP-1301
- FSRU Preliminary schematic overview of process, IPS (SIS), ESD and F & G systems/312383-SAI-DCS-501
- FSRU Preliminary Telecommunication system diagram/312383-SAI-DCS-505

13.11 ELECTRICAL SYSTEM

13.11.1 Design Rules and Regulations Summary

Electrical systems are designed according to IEC standards. Installation of electrical systems and equipment complies with Class Rules and IEC with respect to hazardous and non-hazardous area classification. Additionally, API RP14Z rules will be incorporated to provide a bridging between IEC and NEC regulations.

IEC and API rules were selected for NEC equivalency for the following reasons:

a) Compatibility with other internationally sourced mechanical equipment (e.g motor driven pumps);
b) Consistency of the application of international and Class regulations across the FSRU;
c) Consistency with construction practice in international shipyards;
d) Compatibility with the International Gas Code; and
e) Consistency with LNG carrier practice.

13.11.2 General

The main power generation plant for the FSRU is located externally. The electrical power generation system on the FSRU is self supporting. Normal service dual fuel gas turbines are located on the topsides, each driving an 11 kV, 22 MVA generator, delivering power to an 11kV switchboard. Essential and emergency diesel generators are located in the essential and emergency diesel generator rooms, driving a 6.6 kV system, delivering power to the essential and emergency switchboards. The batteries are installed on battery racks and for the main UPS system dedicated battery rooms are provided (one for the topsides and one for the hull).

Electric power on the LNG FSRU is generated by three sets of gas turbine-driven main generators in an N+1 configuration. The turbine-driven main generators are fuelled by gas when the LNG FSRU is in production. One of the three generator sets is a dual fuel unit and can use low sulfur automotive diesel when LNG is not being vaporized. The main power generation plant also supplies power to the essential and emergency loads under normal operating conditions.

The diesel engine generators are located within the accommodation area at main deck level. They are rated to supply the emergency loads of the complete FSRU in case of an emergency and to operate in parallel with a dual fuel turbine-driven generator. These generator sets are rated to enable the FSRU to start up.

Gas Turbines

The main power plant consists of three gas turbine-driven generator sets. These sets with IP 44, water cooled, insulation class F, brushless and synchronous main generators (AC 11 kV, 60 Hz, 3 Phase, 0.8 pf), are located in an area set aside from the LNG storage and processing area. During normal operating conditions only gas fuel is used for the gas turbines. Low sulfur automotive grade DO is used for start up and emergency situations.

Essential and Emergency Diesel Engine Generators

Three engine generators are located in the essential generator room and in the emergency generator room on the upper deck. Each is rated at 6.6 kV ac., 3 ph, 60 Hz, 2 MW, IP 23, air-cooled, insulation class F.

13.11.3 Electrical Power Distribution

Power is generated in the power plant, the gas turbine-driven generators located on the trunk deck, and with the diesel engine-driven generators located within the accommodation at main deck level. The electrical system arrangement is reflected in the one line diagram, set forth in the appendices, Section 13.11.

Applied Voltage

- HV power AC 11 kV, 60 Hz, 3 Phase;
- MV power AC 6.6 kV, 60 Hz, 3 Phase;
- LV Normal supply system AC 480 V, 60 Hz, 3 Phase;
- Emergency supply system AC 480 V, 60 Hz, 3 Phase;
- Motors above 250 kW AC 11 kV or 6.6 kV, 60 Hz, 3 Phase;
- Motors 250 kW and lower AC 480 V, 60 Hz, 3 Phase;
- Small Motors and Lighting AC 208 V, 60 Hz, 3 Phase or 1 Phase; and
- DC systems DC 24 V

13.11.4 Area Classifications

Hazardous area classification for the FSRU has been determined for the hull and main deck in accordance with the Class Rules and for the topsides in accordance with the Area Classification Code for Petroleum Installations (IP - 15).

All electrical equipment intended for use in hazardous areas is tested and certified for operation in the required zoning by an international, recognized testing authority in accordance with IEC 60079 requirements. The accommodation areas (including working areas), but excluding spaces opening only onto open decks, are designed as gas-safe spaces and are unclassified. Other areas that are designed as gas-safe spaces and are unclassified are the machinery and equipment rooms below and normally accessed from the accommodation and, as far as possible, the internal spaces and deckhouses forward of the accommodation superstructure in the forward end of the FSRU.

In particular, the spaces in the bow containing electrical equipment will be designed as safe spaces (unclassified) and provided with means to maintain their gas safe integrity in the event of an incident on the process deck or mooring tower. If these arrangements cannot be achieved for the bow spaces, and essential services rely on maintaining electrical equipment in operation in the bow, then special protection is provided for the equipment, e.g., air purge and pressurization, or similar measures.

13.11.5 Motor Control Centers

General

Motors and starters for the following equipment are constructed according to the Class Rules:

- Equipment for domestic services such as galley, pantry, laundry, workshop equipment, etc.;
- Provision cranes, hoist, refrigeration provision plant, unit cooler and vacuum toilet;
- Freshwater generator, sewage treatment, calorifier and oily water separator;
- Valve hydraulic power pack; and
- Others motors and starters supplied as a part of packaged equipment.

Motor

In general, motors are of squirrel cage induction type of IEC Standard frame designed for AC 480 V three phase 60 Hz, except the motors for domestic service and small capacity motors of AC 208 V single phase or three-phase type.

Continuous rating for motors is used, except for motors for cranes, davits, etc., which are of intermittent rating according to the Class Rules. Motors installed in the classified area are explosion proof according to the requirements of the Class.

13.11.6 Lighting

Lighting fixtures and fittings are particularly constructed for marine use and either non-waterproof, drip-proof, waterproof or explosion-proof according to their location. In general, the indoor area of the FSRU is adequately illuminated with fluorescent lamps and floodlights, and stores and the outdoor area are illuminated with florescent lamps, incandescent lamps and floodlights. The normal lighting, the emergency lighting, and the emergency lighting with integral battery are fed from AC 208 V, single phase and 60 Hz from distribution boards. Other voltage maybe applied for special lighting, if any, according to the Class Rules.

Fixtures and fittings are generally constructed to meet international standards. Safe access is provided to all lighting fixtures to change bulbs or tubes. For example, a guardrail may be provided for deck lighting posts and steps for lighting may be installed at high levels.

Emergency Lamps

Emergency lights are provided throughout the FSRU to furnish proper illumination for guiding crew to the lifeboat stations and to permit the operation of emergency services when normal power supply fails. Approximately 25% of general illumination lights are fed from the emergency distribution board and used for emergency lights.

Battery Back-Up Emergency Light

The battery operated lamps with an integral battery, inverter unit, and charge unit are located throughout the FSRU to furnish proper illumination for guiding crew to the lifeboat stations when normal and emergency power supplies fail. Approximately 50% of emergency lights have a battery backup emergency light. The battery backup emergency light is started automatically upon failure of the power supply and operates for a period of not less than 60 minutes. All battery backup emergency lights installed in the machinery space and outdoors are explosion-proof type suitable for minimum Zone 2 certification, and are manually switched on/off from the distribution board to which circuits of the lightings are connected. Low location light is not applied.

13.11.7 Switch and Receptacle

Switch

Switches used for the lighting branch circuit are two-pole surface type. In general, switching of lights connected to the FSRU service lighting system is local, i.e., one switch for lights in the space or room at the inside of each entrance, except the outside of entrance for the paint store. Weather deck lights, passage lights, and machinery space lights are divided into suitable groups and controlled by branch circuit breakers in the lighting distribution boards. Switches for berth lights and desk lights are fitted on their own fixtures. Switches for deckhead lights in the rooms of senior crew members' bedrooms are the two-way type; one is fitted at the entrance door, and the other is fitted at the head of bed.

Receptacle

In general, receptacles for general service are National Electrical Manufacturer's Association (NEMA) type two-pole type with earthing connection. In each accommodation inner passage, a suitable number of receptacles for electric cleaners are fitted. Receptacles for general service (about 200 receptacles) are also provided.

Combination box

One surface-type combination outlet box is applied for each cabin, mess room and recreation room.

13.11.8 Navigation Lights and Signal Lights

Navigation Light (for towing)

Navigation lights of double bulb type and an indicator are provided. The navigation light indicator panel is installed on the central control console, with a control switch for each navigation light and an alarm (audible/visual) for the navigation light failure. The navigation light indicator panel is supplied from two separate feeders with a source failure alarm--one from the hull LV switchboard and the other from the emergency switchboard.

Aircraft Warning Light

One set of aircraft warning lights is provided on the radar mast and these lights are remotely controlled (on/off) from the CCR. Aircraft warning lights (mooring tower, cranes and flare tower) are supplied and installed, if necessary.

Navigation Aids System

A navigation aids system is provided in accordance with International Association of Lighthouse Authorities (IALA) "Recommendations for the marking of offshore structures." The main warning light is white, flashing Morse U at 30 second intervals and visible for 10 nautical miles (NM) from points 5 m above sea level. Any subsidiary warning light is red and is visible for 2 NMs from points 5 m above sea level.

The foghorn is audible for a 2 NM range, and is operated at all times when the meteorological visibility is less than 0.5 NM to sound the letter U in Morse Code at intervals of not more than 30 seconds. The warning lights and fog horn sound signal have a reserve source of energy that enable them to be operated for a period of four days in the event of the failure of the main energy supply on the FSRU and automatically comes into operation on the failure of the main energy supply.

Dedicated uninterruptible power supply (UPS) supplies power to the Morse U signal lights. The inverters may be used to convert low DC to high AC voltage to prevent voltage drop. The UPS is fed from two separate feeders with a source failure alarm, one from the hull LV switchboard and the other from the emergency switchboard.

All equipment, except control panel and batteries, of the navigation aids system is explosion-proof type suitable for Zone-1 installation.

The main warning light and the foghorn are located at the FSRU forward area.

Helideck Lighting System (helicopter lights and illuminated windsock)

One complete set of helicopter lights and illuminated windsock is provided in accordance with Civil Aviation Authority (CAA) requirements for day and night operations. The helideck lightings and illumination windsock is remotely controlled (on/off) from the CCR and is fed from dedicated UPS with at least 60 minutes duration. The UPS is fed from two separate feeders with a source failure alarm, one from the hull LV switchboard and the other from the emergency switchboard.

All equipment, except the control panel and UPS, of helideck lighting system are explosion-proof type suitable for Zone-2 installation. All helideck lightings remain illuminated in the event of gas detection around the accommodation block. Quantity and mounting type (surface or recess) of helideck perimeter lights and floodlight meet CAA requirements.

APPENDICES TO RESOURCE REPORT 13.11

Electrical System Appendix
Electrical load list (process design basis)/312383-SAI-LI-501
FSRU Medium voltage one line diagram/312383-WSN-SLD-501
FSRU Low voltage one line diagram/312383-WSN-SLD-502
General Hazardous Area Classification Drawing/312383-SAI-DWG-610
Hull Electric Load Analysis/312383-SHI-CAL-500
Hull One Line Diagram/312383-SHI-DWG-500

13.12 DESIGN CODES AND STANDARDS

13.12.1 General

When defining regulatory requirements for offshore LNG facility installation, design and construction, it is important to include standards that are consistent and non-conflicting and which are appropriate to the lifetime requirements for operating, testing, surveying and certification, repair and maintenance.

Offshore installations such as the FSRU may be designed and constructed in one part of the world and ultimately operated in another part of the world. This presents particular challenges. The fundamental requirements for functional performance and operating safety are universal in nature, but differences in local regulations can significantly impact design and construction details. More detailed information regarding the design codes and standards is provided in the appendices of Section 13.12.

The principal philosophy for ensuring that the appropriate design, construction and operational codes, regulations, and standards are applied is based on the view that a FSRU is essentially an LNG carrier, with additional process and regasification equipment, which is moored at a fixed location.

49 CFR Part 193 and NFPA 59A codes were written to be applied to an onshore facility. Because this facility is a floating installation offshore, some of the standards do not directly apply. The Broadwater LNG facility incorporates the spirit of the safety requirements detailed in 49 CFR Part 193 and NFPA 59A in sections that do not directly apply and complies with all regulations directly where it is appropriate to do so. Section 13.14 discusses which regulations apply, which do not, and provides the rationale for the design decision.

The standards normally associated with an LNG carrier are referred to as "marine" standards. These standards will be applied unless other standards provide greater safety. The case for adopting "marine" standards is further supported by the fact that the FSRU is most likely to be built as a fully integrated unit in a new build shipyard where International "marine" standards are the industry norm.

Based on this, a set of standards is adapted based on federal, state, Class Rules and, as appropriate, International Standards for design and construction that incorporate appropriate federal, state and National requirements.

The design of the FSRU will take into account the following requirements:

- Federal requirements (e.g., CFRs);
- State and local standards;
- International Standards-Class Rules (Inclusive state and federal requirements as per above); plus Gas Code, SOLAS, etc.;
- Industry Guidelines e.g., SIGTTO, OCIMF;
- Industry references not included in the preceding.

The FSRU is designed and built in accordance with the provisions contained in the Class Rules for:

- The Classification of a Floating Offshore Installation at a Fixed Location;
- The Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, which incorporate the IGC Code; and
- Rules and Regulations for the Classification of Ships.

The Floating Offshore Installation rules take precedence. However, multiple rules and standards are applicable for the FSRU and, in general, the more stringent requirement will be applied.

LNG carrier design, construction and operation are comprehensively covered by Rules and guidelines, and the legislative requirements of national and international authorities. LNG carriers are typically constructed according to Classification Society Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, known as Gas Ship Rules. These rules supplement the more general Rules and Regulations for the Classification of Ships. Compliance with the Rules is assured through design appraisal and survey during building and commissioning.

In particular, Class Rules incorporate the requirements of the IMO IGC. The IGC mandates the use of certain standards, including those of the IEC, of direct relevance to marine control and instrumentation. The IGC is underpinned by Unified Interpretations, which all members of the International Associations of Classification Societies (IACS) follow. ABS, LR and DNV, for example, are leading IACS members and are recognized providers of safety and certification services worldwide.

APPENDICES TO RESOURCE REPORT 13.12

Design Codes and Standards Appendix

13.13 PERMITS AND APPROVALS

Required permits for the FSRU are listed in Resource Report 1.

13.14 REGULATORY COMPLIANCE

The following matrix provides a guide to the philosophy used in this design as related to the requirements of 49 CFR Part 193 and NFPA 59A.

For FSRU personnel, training and qualification requirements are set forth in Resource Report 11, section 11.3

49 CFR 193

Subpart	***Section***	***Title***	***Can it be Reasonably Applied?***	***Comments***	***Codes/Standards Referenced by 49 CFR 193***
A - General	2001	Scope of Part	No	Subsection (b)(4) specifically excludes facilities in navigable waterways from the requirements of this Part	Section 3(8), 16 U.S.C. 196(8) (Natural Gas Act)
A - General	2005	Applicability	No per above		
A - General	2007	Definitions	nmf		
A - General	2009	Rules of regulatory construction	Yes	Defines meaning of terms used through the Part	
A - General	2011	Reporting	Yes	Spill reporting	
A - General	2013	Incorporation by reference	nmf		Various external sources utilized in later sections
A - General	2017	Plans and procedures	Yes		49 CFR 190.237
A - General	2019	Mobile and temporary LNG facilities	No	Not a temporary facility	NFPA 59A
B - Siting Requirements	2051	Scope	Partially		NFPA 59A
B - Siting Requirements	2057	Thermal radiation protection	Partially	LNGFIRE is not designed for use with this type of facility; Sandia findings for calculation of thermal hazard zones around FSRU will be applied	NFPA 59A, Section 2.2.3.2 GRI-89/0176 "LNGFIRE: A Thermal Radiation Model for LNG Fires"

Subpart	Section	Title	Can it be Reasonably Applied?	Comments	Codes/Standards Referenced by 49 CFR 193
B - Siting Requirements	2059	Flammable vapor-gas dispersion protection	Partially	Intend to use the marine appropriate combination of the 2004 Sandia study "Guidance on Risk Analysis and Safety Implication of a Large Liquified Natural Gas (LNG) Spill Over Water" and DNV's 2004 publication "Consequences of LNG Marine Incidents".	NFPA 59A, Sections 2.2.3.3, 2.2.3.4, and 2.2.3.5 GRI-89/0242 "LNG Vapor Dispersion Prediction with the DEGADIS Dense Gas Dispersion Model" GRI-96/0396.5 "Evaluation of Mitigation Methods for Accidental LNG Releases, Volume 5: Using FEM3A for LNG Accident Consequence Analysis"
B - Siting Requirements	2067	Wind forces	Yes	Useful for process equipment and topside structures; would have to be used in combination with Class/marine guidelines	ASCE 7-95 "Minimum Design Loads for Buildings and Other Structures"
C - Design	2101	Scope	No	This Subpart is written almost exclusively for facilities built onshore.	NFPA 59A
C - Design	2119	Records	Yes	Standard practice to maintain records on materials of design	
C - Design	2155	Structural requirements	Partially	FAA requirements are met; otherwise applies to design of impounding areas	14 CFR Section 1.1
C - Design	2161	Dikes, general	No	No diked areas. Spill design is to move LNG overboard; channels are included	
C - Design	2167	Covered systems	No	No covered areas	

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
C - Design	2173	Water removal	No	No diked areas; water is handled in separate drains	National Weather Service "Rainfall Frequency Atlas of the United States"
C - Design	2181	Impoundment capacity; LNG storage tanks	No	No diked areas	
C - Design	2187	Nonmetallic membrane liner	Yes		
D - Construction	2301	Scope	Partially	To the extent that the NFPA 59A reference can be applied to offshore construction	NFPA 59A
D - Construction	2303	Construction acceptance	No	Inspection and testing must be performed at the fabrication yard and the standards to be applied are primarily from marine and Classification rules	NFPA 59A
D - Construction	2304	Corrosion control overview	Yes	Part of a solid mechanical integrity program	
D - Construction	2321	Nondestructive tests	No	Inapplicable for membrane tanks; testing is per IGC requirements for membrane tanks	ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
E - Equipment	2401	Scope	Yes, with exceptions for electrical and marine	Though no section is specifically referenced, by implication this Subpart refers to Sections 5 through 7 of NFPA 59A. Section 5 (Vaporizers) of NFPA 59A can be applied in whole; Section 6 (Piping Systems and Components) of NFPA 59A can be applied to the extent that it does not conflict with IGC Code or Classification rules; and Section 7 (Instrumentation and Electrical Services) of NFPA 59A can have the parts not applying to above ground storage tanks or the NEC (NFPA 70) utilized to the extent that they do not conflict with IGC Code or Classification rules. The process equipment is utilizing the IEC for electrical codes.	NFPA 59A
E - Equipment	2441	Control center	Yes	Control center is in the Accommodation area, far end from process equipment	
E - Equipment	2445	Sources of power	Yes	Redundancy and separate emergency	

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
				generator locations standard part of design	
F - Operations	2501	Scope	Yes	Standard operating procedures cover most of the items below	
F - Operations	2503	Operating procedures	Yes		
F - Operations	2505	Cooldown	Yes		
F - Operations	2507	Monitoring operations	Yes		
F - Operations	2509	Emergency procedures	Yes		
F - Operations	2511	Personnel safety	Yes		
F - Operations	2513	Transfer procedures	Yes	Only applies to transfers between FSRU and LNGC (no tank cars or tank trucks)	AGA "Purging Principles and Practices"
F - Operations	2515	Investigations of failures	Yes		49 U.S.C. 60101
F - Operations	2517	Purging	Yes	Would be coordinated with any marine/Classification rules and practices	AGA "Purging Principles and Practices"
F - Operations	2519	Communication systems	Yes		
F - Operations	2521	Operating records	Yes		NFPA 59A

Subpart	Section	Title	Can it be Reasonably Applied?	Comments	Codes/Standards Referenced by 49 CFR 193
G - Maintenance	2601	Scope	Yes	Standard operating procedures cover most of the items below; corrosion control covered by mechanical integrity program	
G - Maintenance	2603	General	Yes	Includes lockout/tagout	
G - Maintenance	2605	Maintenance procedures	Yes		49 CFR 191.23
G - Maintenance	2607	Foreign material	Yes		
G - Maintenance	2609	Support systems	Yes		
G - Maintenance	2611	Fire protection	Yes		
G - Maintenance	2613	Auxiliary power sources	Yes	Monthly testing	
G - Maintenance	2615	Isolating and purging	Yes		AGA "Purging Principles and Practices"
G - Maintenance	2617	Repairs	Yes		
G - Maintenance	2619	Control systems	Yes	Includes testing periods for types of control systems (for example, 6 months for fire protection systems)	
G - Maintenance	2621	Testing transfer hoses	N/A	No hoses	
G - Maintenance	2623	Inspecting LNG storage tanks	No	Application to above ground or in-ground storage tanks; insulation effectiveness (subsection	

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
				(c)) may be covered by IGC Codes	
G - Maintenance	2625	Corrosion protection	Yes		
G - Maintenance	2627	Atmospheric corrosion control	Yes		
G - Maintenance	2629	External corrosion control: buried or submerged components	Yes		49 CFR 192.461 49 CFR 192.463
G - Maintenance	2631	Internal corrosion control	Yes		
G - Maintenance	2633	Interference currents	Yes		
G - Maintenance	2635	Monitoring corrosion control	Yes		49 CFR 192.463
G - Maintenance	2637	Remedial measures	Yes		
G - Maintenance	2639	Maintenance records	Yes		NFPA 59A
H - Personnel Qualifications and Training	2701	Scope	Yes	Will be covered by management systems for Broadwater Energy	
H - Personnel Qualifications and Training	2703	Design and fabrication	Yes		
H - Personnel Qualifications	2705	Construction, installation, inspection,	Yes		

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
and Training		and testing			
H - Personnel Qualifications and Training	2707	Operations and maintenance	Yes		
H - Personnel Qualifications and Training	2709	Security	Yes		
H - Personnel Qualifications and Training	2711	Personnel health	Yes		
H - Personnel Qualifications and Training	2713	Training: operations and maintenance	Yes	Includes all personnel being trained to give first aid; training to be provided on a minimum 2-year cycle	
H - Personnel Qualifications and Training	2715	Training: security	Yes	Training to be provided on a minimum 2-year cycle	
H - Personnel Qualifications and Training	2717	Training: fire protection	Yes	Training to be provided on a minimum 2-year cycle	
H - Personnel Qualifications and Training	2719	Training: records	Yes		

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
I - Fire Protection	2801	Fire protection	No	NFPA 59A is inadequate for fire protection for the FSRU. A combination of primarily 33 CFR 149 and the IGC Code for will be applied to the hull sections, and NFPA 59A for the topsides will be applied.	NFPA 59A, Sections 9.1 through 9.7 and Section 9.9 - by extension this includes portions of: NFPA 10 Standard for Portable Fire Extinguishers NFPA 72 National Fire Alarm Code NFPA 600 Standard on Industrial Fire Brigades NFPA 1221 Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems NFPA 1901 Standard for Automotive Fire Apparatus
J - Security	2901	Scope	Yes	Will be covered by standard operating procedures for the FSRU	
J - Security	2903	Security procedures	Yes		
J - Security	2905	Protective enclosures	Yes (philosophical ly)	The entire FSRU will be considered a protective enclosure	
J - Security	2907	Protective enclosure construction	Yes		
J - Security	2909	Security communications	Yes	Communication on the FSRU and with law enforcement (assumed to be USCG)	
J - Security	2911	Security lighting	Yes		

Subpart	*Section*	*Title*	*Can it be Reasonably Applied?*	*Comments*	*Codes/Standards Referenced by 49 CFR 193*
J - Security	2913	Security monitoring	Yes		
J - Security	2915	Alternative power sources	Yes	This assumes that emergency power also includes exterior lighting	
J - Security	2917	Warning signs	Partially	Will follow security guidance from 33 CFR 150 Subpart J, §150.900 through §150.940	

NFPA 59A

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
Chapter 1	**General**	Terminology	Information	
Chapter 2	**Plant siting and layout**			
§ 2.1	Plant site provisions	(a) Minimum clearances	No	Use offshore standards
§ 2.1.1	Factors of selection for plant site location			
		(b) All-weather accessibility	No. Offshore safety prevails	
		(c) Protection against forces of nature	Yes	
		(d) Other safety contributors factors	Offshore safety prevails	
§ 2.1.2	Site preparation	Site preparation for retention of spilled LNG, flammable refrigerants and flammable liquids within the limits of plant property and for surface water drainage	No	IGC guidance for LNG Carriers to be used
§ 2.1.3	MAWP	Mention of it for all components	Yes	
§ 2.1.4	Soil and general investigations		Yes	
§ 2.2	Major site provisions for Spill and Leak Control			
§ 2.2.1	General			
§ 2.2.1.1		Provisions to minimize the possibility of accidental discharge of LNG at containers from endangering adjoining property or important process equipment or from reaching waterways		
		(a) Impounding area surrounding the container	No	
		(b) Impounding area formed by …	No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
		(c) where container is constructed below surrounding grade	No	
§ 2.2.1.2	Drainage / Impoundment	Drainage / Impoundment for (1) Process areas, (2) Vaporization Areas, (3) Transfer Areas for LNG, flammable refrigerants and flammable liquids and (4) areas surrounding storage of such fluids	No, only drainage of process areas is practical for offshore facilities	
§ 2.2.1.3		Waiver conditions	No	
§ 2.2.1.4		Flammable liquid and flammable refrigerant storage not to be located with LNG container impounding area	No	However, there is no such impounding area for Broadwater
§ 2.2.2	Impounding Area and Drainage System Design and Capacity			
§ 2.2.2.1		Design volumes for impounding areas serving LNG containers	No	
§ 2.2.2.2		Design volumes for impounding areas of other gas or LNG process areas (single accidental leakage during a 10-minute period or a shorter time period based upon demonstrable surveillance and shutdown provisions giving the greatest volume of LNG)	No	Design basis to focus on largest practical release of LNG given multiple safeguards.
§ 2.2.2.3		Enclosed drainage channels prohibited	No	Only potential for enclosed drainage may be in design of discharge system from facility - that is, a pipe leading to an opening in the side of the FSRU (gravity feed).
§ 2.2.2.4		Design of dikes, impounding walls and drainage systems	No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 2.2.2.5		Conformance of dikes, impounding walls and drainage channels to NFPA30	No, except for drain segregation	Segregation of drains from cryogenic areas and non-cryogenic areas, which means that LNG and non-LNG spills are handled separately.
§ 2.2.2.6		Height of dikes and impounding walls	No	
§ 2.2.2.7		Rain water drainage of impounding areas	No	Segregation of drains from cryogenic areas and non-cryogenic areas, which means that LNG and non-LNG spills are handled separately.
§ 2.2.2.8		Insulation systems for impounding areas	No	
§ 2.2.3	Impounding area siting		No	
§ 2.2.3.2		Damaging effects of fire reaching beyond a property line: thermal radiation distances shall be calculated in accordance with the model described in Gas Research Institute report GRI 0176 "LNGFIRE: A Thermal Radiation Model for LNG Fires"	No	Guidance for the FSRU is taken from the Sandia study
§ 2.2.3.3		Spacing of a LNG tank impoundment to the property line	No	Guidance for the FSRU is taken from the Sandia study
§ 2.2.3.4		Provisions to minimize the possibility of a flammable mixture of vapors from a design spill specified in § 2.2.3.5 reaching a property line that can be built upon	No	Guidance for the FSRU is taken from the Sandia study; note also that site is surrounded by open water.

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 2.2.3.5		Design spill from a container with over-the-top fill and no penetrations below the liquid level : The largest flow from any single line that could be pumped into the impounding area with the container withdrawal pump(s) considered to be delivered the full rated capacity for 10 minutes if surveillance and shutdown is demonstrated and approved by the authority having jurisdiction or for the time needed to empty a full container if not	See Section 13.12	Design basis to focus on largest practical release of LNG given multiple safeguards.
		Design spill from vaporization, process or LNG transfer areas: The largest flow from any single line that could be pumped into the impounding area with the container withdrawal pump(s) considered to be delivered the full rated capacity for 10 minutes or a shorter time based on demonstrable surveillance and shutdown provisions acceptable to authority having jurisdiction.	No	Credible leak hole size for 1 minute as the Fire & Gas detection and the ESD systems react immediately to the release and shutdown all LNG process systems
§ 2.2.3.6		Location of LNG container impounding area to be located so that the heat flux from a fire over the impounding area shall not cause major structural damage to any LNG marine carrier	No	A similar approach is employed. The spilled LNG disposal is located on the opposite side to the LNG carrier
§ 2.2.3.7		All connections on containers to be equipped with automatic fail-safe valves closing on fire detection, excess flow detection, gas detection or manual demand [there are exceptions]	Yes	
§ 2.2.3.8		Safety distances from impounding areas to property line or waterways (not less than 50 ft)	No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 2.2.4	Container spacing	Minimum distance between storage containers : 25% of the sum of diameters of adjacent containers (1.5 m minimum)	No	IGC code and classification rules apply.
§ 2.2.5	Vaporizer spacing			
§ 2.2.5.1		Vaporizers and associated primary heat source to be located at least 15 m from any other source of ignition (adjacent vaporizer or primary heat source are not to be considered a source of ignition for this application)	Yes	
§ 2.2.5.2		SCV to be located at least 30 m from a property line that can be built upon and at least 15 m from any LNG impoundment or path of LNG travel from a source of accidental discharge, any storage containers or unfired process equipment handling LNG or flammable liquid, refrigerant or gas, loading and unloading arms, control buildings, offices, shops and other occupied plant structures	No	
§ 2.2.5.1		Minimum 1.5 m clearance between vaporizers	Yes	
§ 2.2.6	Process equipment spacing	Process equipment containing LNG, refrigerants, flammable liquids or gases to be located at least 15 m from sources of ignition, control rooms, offices, shops and other occupied structures	No	
		Fired equipment and other sources of ignition to be located at least 15 m from any impounding area or container drainage system	No	
§ 2.2.7	Loading and Unloading Facility Spacing			
§ 2.2.7.1		Spacing from bridge	No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 2.2.7.2		LNG loading and unloading connections to be at least 15 m from process areas, storage containers, control buildings, offices, shops and other occupied or important plant structures	No	Aside from the storage tanks, these spacing requirements are likely met with the Broadwater layout.
§ 2.3	Buildings and structures			
§ 2.3.1		Buildings / enclosures with LNG inside	No	
§ 2.3.2		Idem	Yes, BOG compressor room	
§ 2.3.3		Other buildings - See § 9.4.1		
§ 2.3.4		Temporary use of LNG portable equipment	No	
§ 2.3.5		Spacing table 2.2.4.1 applicable to odorization equipment of emergency facility	Not Applicable	
§ 2.4	Designer and Fabricator Competence		Yes	
§ 2.5	Soil Protection for Cryogenic Equipment		Yes	
§ 2.6	Falling Ice and Snow		Yes	
§ 2.7	Concrete Materials		No	Steel Hull
Chapter 3	**Process equipment**			
§ 3.1	General	Installation criteria	Yes, except (2)	(2) is only applicable to onshore buildings
§ 3.2	General	Process design criteria	Yes, except (2)	(2) is only applicable to onshore buildings
§ 3.2.1		Construction Materials for pumps and compressors	Yes	
§ 3.2.2		Valving around pumps and compressors	Yes	
§ 3.2.3		Pressure-relieving devices on pump and compressor discharge	Yes	
§ 3.2.4		Overpressure protection of pump casing	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 3.3	Flammable Refrigerant and Flammable Liquid Storage	Installation requirements as per relevant NFPA and API codes	No	No refrigerant, but possible small storage quantities of lubricants and other flammable materials.
§ 3.4	Process Equipment			
§ 3.4.1		Siting requirements to be in accordance with § 2.2	Applicable on a case by case basis	
§ 3.4.2		Boilers	None in topsides - Perhaps in the hull but other code should then apply	IGC code for placement in machinery space.
§ 3.4.3		Design of shell and tube exchangers as per TEMA standards and Pressure Testing / Inspection as per ASME Section VIII	Yes	
§ 3.4.4		Design of gas turbines as per NFPA 37	Yes	
§ 3.4.5		Design of boil-off system	Yes	
§ 3.4.6		Vacuum breaking system requirements	Yes	
Chapter 4	**Stationary LNG Storage Containers**		No	Membrane technology applied on the FSRU
§ 4.1	General			
§ 4.1.1	Inspection		No	Will utilize US Coast Guard requirements for safety and inspection of offshore LNG terminals and FPSOs.
§ 4.1.2	Basic Design Considerations			
§ 4.1.2.1		Specification of MAWP and Maximum Allowable Vacuum by the Operator	Yes	
§ 4.1.2.2		Physical and chemical compatibility with LNG service of containers parts in contact with LNG or cold LNG vapors	Yes	

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 4.1.2.3		Piping design standard as per chapter 6 of NFPA 59A	No, piping within LNG container is designed to meet IGC code	
§ 4.1.2.4		Both top and bottom filling requirements	Yes	
§ 4.1.2.5		Protection of container outer surface area from LNG spills	To be assessed in conjunction with LNG spill and containment philosophy	
§ 4.1.2.6		Protection of container foundations against contact with LNG accumulated in the dike	No	
§ 4.1.2.7		Definition of the LNG density (in no case, less than 470 kg/m3)	Yes	
§ 4.1.2.8		Provisions for removal of the container from service	No, IGC code applies	
§ 4.1.3	Seismic design		No	As a floating facility, the FSRU must comply with US Coast Guard and classification design requirements for handling associated loads.
§ 4.1.4	Wind and Snow Loads		Yes	
§ 4.1.5	Container Insulation		No, the membrane technology used for Broadwater FSRU is not covered by NFPA 59A	It is covered by IGC codes.
§ 4.1.6	Filling Volume	Requirements for containers designed to operate at a pressure in excess of 15 psi	No	Pressure design and relief by applicable IGC codes.
§ 4.1.7	Foundations		No	
§ 4.2	Metal Containers		No, the membrane technology used for Broadwater FSRU is not covered by NFPA 59A	IGC code.
§ 4.3	Concrete Containers		No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 4.4	Marking of LNG Containers		No	IGC code and classification rules apply.
§ 4.5	Testing of LNG Containers		No	IGC code and classification rules apply.
§ 4.6	Container Purging and Cooldown	Container to be purged and cooled in accordance with § 11.3.5 and § 11.3.6 prior to being put in service		
§ 4.7	Relief Devices			
§ 4.7.1	General	Containers equipped with pressure and vacuum relief devices in accordance with API 620 (operating pressure below 15 psi) or ASME Section VIII (operating pressure above 15 psi)	No	IGC code and classification rules apply.
§ 4.7.2		Design of Relief and Vacuum devices		
§ 4.7.2.1			Yes	
§ 4.7.2.2		No more than one stop valve shall be closed at one time	Yes	
§ 4.7.2.3		Safety relief valve discharge stacks or vents to be designed and installed to prevent accumulation of water, ice, snow and to discharge upwards	Yes	Flare is designed according to applicable codes for weather.
§ 4.7.3	Relief Device Sizing			
§ 4.7.3.1	Pressure Relief	Basis for determining the capacity of pressure relief devices	Yes, except fire exposure	A fire could only occur on the hull main deck or along the hull, giving limited heat input to LNG containment.
§ 4.7.3.2	Minimum Capacity	Not less than 3% of the full tank contents within 24 hours	IGC code prevails	
§ 4.7.3.3	Vacuum Relief	Capacity based on (1) withdrawal of liquid or vapor at the maximum rate, (2) rise in barometric pressure, (3) reduction in vapor space pressure as a result of filling with subcooled liquid - Calculation conditions	Yes	
§ 4.7.3.4	Fire Exposure		No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
Chapter 5	**Vaporization Facilities**			
§ 5.1	Classification of Vaporizers		Information	
§ 5.2	Design and Materials of Construction			
§ 5.2.1		Vaporizers shall be designed, fabricated, and inspected in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1. Because these vaporizers operate over a temperature range of -260°F to +100°F (-162°C to +37.7°C), the rules of the ASME *Boiler and Pressure Vessel Code*, Section I, Part PVG, are not applicable.	Yes	
§ 5.2.2		Vaporizer heat exchangers shall be designed for a working pressure at least equal to the maximum discharge pressure of the LNG pump or pressurized container system supplying them, whichever is greater.	Yes	
§ 5.3	Vaporizer Piping and Intermediate Fluid Piping and Storage			
§ 5.3.1		Manifolded vaporizers shall have both inlet and discharge block valves at each vaporizer.	Yes	
§ 5.3.2		The discharge valve of each vaporizer and the piping components and relief valves installed upstream of each vaporizer discharge valve shall be designed for operation at LNG temperatures [-260°F (-162°C)].	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 5.3.3		Automatic equipment shall be provided to prevent the discharge of either LNG or vaporized gas into a distribution system at a temperature either above or below the design temperatures of the sendout system. Such automatic equipment shall be independent of all other flow control systems and shall incorporate a line valve(s) used only for emergency purposes.	Yes	
§ 5.3.4		Isolation of an idle manifolded vaporizer to prevent leakage of LNG into that vaporizer shall be accomplished with two inlet valves, and a safe means shall be provided to dispose of the LNG or gas that can accumulate between the valves. Ambient vaporizers having inlets of 2 in. (50 mm) or less shall not be required to comply with this provision.	Yes	
§ 5.3.5		Each heated vaporizer shall be provided with a device to shut off the heat source. The device shall be operated both locally and remotely. The remote location shall be at least 50 ft (15 m) from the vaporizer.	Yes	
§ 5.3.6		A shutoff valve shall be installed on the LNG line to a heated vaporizer at least 50 ft (15 m) from the vaporizer. If the vaporizer is installed in a building, the shutoff valve shall be installed at least 50 ft (15 m) from the building. The shutoff valve shall be operable either at its installed location or from a remote location, and the valve shall be protected from becoming inoperable due to external icing conditions.	Yes/No	Pure physical distance may be impractical for FSRU; instead, protection barriers may be put in place to offer equivalent safety level for valve operation.

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 5.3.7		Any ambient vaporizer or a heated vaporizer installed within 50 ft (15 m) of an LNG container shall be equipped with an automatic shutoff valve in the liquid line. This valve shall be located at least 10 ft (3 m) from the vaporizer and shall close when loss of line pressure (excess flow) occurs, when abnormal temperature is sensed in the immediate vicinity of the vaporizer (fire), or when low temperature in the vaporizer discharge line occurs. At attended facilities, remote operation of this valve from a point at least 50 ft (15 m) from the vaporizer shall be permitted.	Yes	
§ 5.3.8		If a flammable intermediate fluid is used with a remote heated vaporizer, shutoff valves shall be provided on both the hot and cold lines of the intermediate fluid system. The controls for these valves shall be located at least 50 ft (15 m) from the vaporizer.	Yes	Intermediate heating medium will be non-flammable glycol water mixture.
§ 5.4	Relief devices on vaporizers		Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 5.4.1		Each vaporizer shall be provided with a safety relief valve(s) sized in accordance with either of the following requirements. (a) The relief valve capacity of heated or process vaporizers shall be such that the relief valve(s) discharges 110 percent of rated vaporizer natural gas flow capacity without allowing the pressure to rise more than 10 percent above the vaporizer maximum allowable working pressure. (b) The relief valve capacity for ambient vaporizers shall be such that the relief valve(s) discharges at least 150 percent of rated vaporizer natural gas flow capacity (as specified for standard operating conditions) without allowing the pressure to rise more than 10 percent above the vaporizer maximum allowable working pressure.	Yes	(b) is not applicable.
§ 5.4.2		Relief valves to be located in a manner as to not be subject to temperatures exceeding 60°C during normal operation unless designed to withstand such temperatures	Yes	
§ 5.5	Combustion Air Supply	Combustion air required for the operation of integral heated vaporizers or the primary heat source for remote heated vaporizers shall be taken from outside a completely enclosed structure or building.	Yes	
§ 5.6	Products of combustion	Where integral heated vaporizers or the primary heat source for remote heated vaporizers is installed in buildings, provisions shall be made to prevent the accumulation of hazardous products of combustion.	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
Chapter 6	**Piping Systems and Components**			
§ 6.1	General			
§ 6.1.1		All piping systems shall be in accordance with ASME B 31.3, Process Piping. The additional provisions of this chapter shall apply to piping systems and components for flammable liquids and flammable gases with service temperatures below -20°F (-29°C). Exception: Fuel gas systems covered by NFPA 54, National Fuel Gas Code.	Yes	
§ 6.1.2		The seismic ground motion used in the piping design shall be the OBE. The piping loads shall be determined by a dynamic analysis or by applying an amplification factor of 0.60 to the maximum design spectral acceleration, SDS. The allowable stress for the piping shall be in accordance with the requirements of ASME B 31.3, Process Piping.	No	FSRU is a floating facility; US Coast Guard and classification safety rules will apply.
§ 6.1.3		Piping systems and components shall be designed to accommodate the effects of fatigue resulting from the thermal cycling to which the systems are subjected. Particular consideration shall be given where changes in size of wall thickness occur between pipes, fittings, valves, and components.	Yes	
§ 6.1.4		Provision for expansion and contraction of piping and piping joints due to temperature changes shall be in accordance with ASME B 31.3, Process Piping, Section 319.	Yes	Also provision for Hull hogging and sagging

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 6.2	**Materials of Construction**			
§ 6.2.1	**General**			
§ 6.2.1.1		All piping materials, including gaskets and thread compounds, shall be used with the liquids and gases handled throughout the range of temperatures to which they are subjected. The temperature limitations for pipe materials shall be as specified in ASME B 31.3, Process Piping.	Yes	
§ 6.2.1.2		Piping that can be exposed to the cold of an LNG or refrigerant spill or the heat of an ignited spill during an emergency where such exposure could result in a failure of the piping that would significantly increase the emergency shall be in accordance with one of the following: (1) Made of material(s) that can withstand both its normal operating temperature and the extreme temperature to which it might be subjected during the emergency (2) Protected by insulation or other means to delay failure due to such extreme temperatures until corrective action can be taken by the operator (3) Capable of being isolated and having the flow stopped where piping is exposed only to the heat of an ignited spill during the emergency.	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.2.1.3		Piping insulation used in areas where the mitigation of fire exposure is necessary shall be made of material(s) that cannot propagate fire in the installed condition and shall maintain any properties that are necessary during an emergency when exposed to fire, heat, cold, or water, as applicable.	Yes	
§ 6.2.2	**Piping**			
§ 6.2.2.1		Furnace lap weld and furnace butt shall not be used. Where longitudinal or spiral weld pipe is used (welded with or without filler metal), the weld and heat-affected zone shall comply with Section 323.22 of ASME B 31.3, Process Piping.	Yes	
§ 6.2.2.2		Threaded pipe shall be at least Schedule 80.	Yes	
§ 6.2.2.3		A liquid line on a storage container, cold box, or other major item of insulated equipment external to the outer shell or jacket, whose failure can release a significant quantity of flammable fluid, shall not be made of aluminum, copper or copper alloy, or other material that has low resistance to flame temperatures. Transition joints shall be permitted to be used where protected against fire exposure. Exception No. 1: Liquid lines protected against fire exposure Exception No. 2: Loading arms and hoses	Yes	
§ 6.2.2.4		Cast iron, malleable iron and ductile iron pipe shall not to be used	Yes, only applicable to process	Hull piping and valve systems will comply with IGC codes and classification rules.

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.2.3	**Fittings**			
§ 6.2.3.1		Threaded nipples shall be at least Schedule 80	Yes	
§ 6.2.3.2		Cast iron, malleable iron, and ductile iron fittings shall not be used.	Yes	
§ 6.2.3.3		Bends shall be permitted only in accordance with ASME B 31.3, Process Piping, Section 332.	Yes	
§ 6.2.3.4		Solid plugs or bull plugs made of at least Schedule 80 seamless pipe shall be used for threaded plugs.	Yes	
§ 6.2.3.5		Compression-type couplings not to be used where subject to temperatures below -29°C Exception for couplings meeting the requirements of ASME B31.3, Section 315	Yes	
§ 6.2.4	**Valves**			
§ 6.2.4.1		In addition to complying with ASME B 31.3, Process Piping, Section 307, valves shall comply with ASME B 31.5, Refrigeration Piping; ASME B 31.8, Gas Transmission and Distribution Piping Systems; or API 6D, Specification for Pipeline Valves, if design conditions fall within the scope of these standards.	Yes	
§ 6.2.4.2		Cast iron, malleable iron, and ductile iron valves shall not be used.	Yes	Hull piping and valve systems will comply with IGC codes and classification rules.
§ 6.3	**Installation**			

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.3.1	**Bolted connections**	Care shall be taken to ensure the tightness of all bolted connections. Spring washers of similar devices designed to compensate for the contraction and expansion of bolted connections during operating cycles shall be used where required.	Yes	
§ 6.3.2	**Piping joints**		Yes	
§ 6.3.2.1		Pipe joints of 2 in. (50 mm) nominal diameter or less shall be threaded, welded or flanged. Pipe joints larger than 2 in. (50 mm) nominal diameter shall be welded or flanged. Exception to joints of 4 in. (100 mm) nominal diameter or less shall be emitted to be threaded where necessary for special connections to equipment or components, where the connection is not subject to fatigue-producing stress.	Yes	For Broadwater all joints are welded
§ 6.3.2.2		The number of threaded or flanged joints shall be kept to a minimum and used only where necessary, such as at material transitions or instrument connections, or where required for maintenance. If threaded joints are unavoidable, they shall be seal-welded or sealed by other means proven by test.	Yes	
§ 6.3.2.3		Metals shall be permitted to be joined for cryogenic service by silver brazing. Silver brazing shall be permitted to be used in joining copper to itself, to copper alloy, and to stainless steel. Dissimilar metals shall be joined by flanges or transition joint techniques that have been proven by test.	Yes	
§ 6.3.2.4		The selection of the gasket material shall include the consideration of exposure to fire.	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.3.3	**Valves**		Yes	
§ 6.3.3.1		Extended bonnet valves shall be installed with packing seals in a position that prevents leakage or malfunction due to freezing. If the extended bonnet in a cryogenic liquid line is installed at an angle greater than 45 degrees from the upright vertical position, evidence of satisfactory service in the installed position shall be demonstrated.	Yes	
§ 6.3.3.2		Shutoff valves shall be provided on container, tank and vessel connections. Exception to (1) Relief valve connections – shutoff valves shall be permitted only at connections for relief valves in accordance with the ASME Boiler and Pressure Vessel Code, section VIII, Division I, UG-125 (d), and Appendix M, M-5 and M-6. (2) Connections for liquid level alarms shall be as required by 7.1.1.2. (3) Connections that are blind flanged or plugged. Shutoff valves shall be located as close as practical to such containers, tanks, and vessels and shall be located inside the impounding area.	Yes	However, there is no such impounding area for Broadwater.
§ 6.3.3.3		The design and installation of an internal valve shall be such that any failure of the penetrating nozzle resulting from external pipe strain is beyond the shutoff seats of the internal valve itself.	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.3.3.4		In the design of the piping system, consideration shall be given to the installation of shutoff or block valves as a means of limiting the contained volume that could be discharged in the event of a piping system failure. (a) Sufficient valves shall be provided that can be operated both at the installed location and from a remote location to allow shutdown of the process and transfer systems by system or area, or to allow complete shutdown in the event of an emergency. (b) In addition to the provisions of 6.3.3.2, container connections larger than 1 in. (25 mm) nominal diameter and through which liquid can escape shall be equipped with at least one of the following: (1) A valve that closes automatically if exposed to fire (2) A remotely controlled, quick-closing valve that shall remain closed except during the operating period (3) A check valve on filling connections	Yes	
§ 6.3.3.5		Valves and valve controls shall be designed to allow operation under icing conditions if such conditions can exist.	Yes	
§ 6.3.3.6		Powered operators shall be provided for emergency shutoff valves that would require excessive time to operate during an emergency or if the valve is 8 in. (200 mm) or larger. Means for manual operation shall be provided.	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.3.4	**Welding**			
§ 6.3.4.1		Qualification and performance of welders shall be in accordance with Section 328.2 of ASME B 31.3, Process Piping, and 6.3.4.2 of this standard.	Yes	
§ 6.3.4.2		Where welding impact-tested materials, qualified welding procedures shall be selected to minimize degradation of the low-temperature properties of the pipe material. Where welding attachments to unusually thin pipe, procedures and techniques shall be selected to minimize the danger of burn-through.	Yes	
§ 6.3.4.3		Oxygen-fuel gas welding shall not be permitted.	Yes	
§ 6.3.5	**Pipe Marking**	Markings on pipe shall comply with the following a) Markings shall be made with a material compatible with the basic material or with a round-bottom, low-stress die. Exception to Materials less than 1/4 in. (6.35 mm) in thickness shall not be die-stamped (b) Marking materials that are corrosive to the pipe material shall not be used. Under some conditions, marking materials containing carbon or heavy metals can cause corrosion of aluminum. Marking materials containing chloride or sulfur compounds cause corrosion of some stainless steels. Chalk, wax-base crayons, or marking inks with organic coloring shall be permitted to be used.	Yes	

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 6.4	**Pipe Supports**			
§ 6.4.1		Pipe supports, including any insulation systems used to support pipe whose stability is essential to plant safety, shall be resistant to or protected against fire exposure, escaping cold liquid, or both, if they are subject to such exposure.	Yes	
§ 6.4.2		Pipe supports for cold lines shall be designed to prevent excessive heat transfer, which can result in piping restraints caused by ice formations or embrittlement of supporting steel. The design of supporting elements shall conform to ASME B 31.3, Process Piping, Section 321.	Yes	
§ 6.5	**Piping Identification**	Piping shall be identified by color-coding, painting, or labeling. Any existing company color code scheme for the identification of piping systems shall be permitted to be used.	Yes	
§ 6.6	**Inspection and Testing of Piping**			
§ 6.6.1	**Pressure Testing**	Pressure tests shall be conducted in accordance with ASME B 31.3, Process Piping, Section 345. To avoid possible brittle failure, carbon and low-alloy steel piping shall be pressure tested at metal temperatures suitably above their nil ductility transition temperature.	Yes	
§ 6.6.2	**Record Keeping**	Records of pressure, test medium temperature, and ambient temperature shall be maintained for the duration of each test and these records shall be maintained for the life of the facility or until such time as a retest is conducted.	Yes	

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 6.6.3	**Welded Pipe Test**		Yes	
§ 6.6.3.1		Longitudinal or spiral welded pipe that is subjected to service temperatures below -20°F (-29°C) shall have a design pressure of less than 2/3 of the mill proof test pressure or subsequent shop or field hydrostatic test pressure. Exception to Pipe that has been subjected to 100 percent radiographic or ultrasonic inspection of the longitudinal or spiral weld.	Yes	
§ 6.6.3.2		All circumferential butt welds shall be examined fully by radiographic or ultrasonic inspection. Exception No. 1: Liquid drain and vapor vent piping with an operating pressure that produces a hoop stress of less than 20 percent specified minimum yield stress shall not be required to be nondestructively tested if it has been inspected visually in accordance with ASME B 31.3, Process Piping, Section 344.2. Exception No. 2: Pressure piping operating above -20°F (-29°C) shall have 30 percent of each day's circumferentially welded pipe joints nondestructively tested over the entire circumference in accordance with ASME B 31.3.	Yes	
§ 6.6.3.3		All socket welds and fillet welds shall be examined fully by liquid penetrant or magnetic particle inspection.	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.6.3.4		All fully penetrated groove welds for branch connections (as required by ASME B 31.3, Process Piping, Section 328.5.4) shall be examined fully by in-process examination in accordance with ASME B 31.3, Section 344.7, as well as by liquid penetrant or magnetic particle techniques after the final pass of the weld. Exception: If specified in the engineering design or specifically authorized by the inspector, examination by radiographic or ultrasonic techniques shall be permitted to be substituted for the examinations required by 6.6.3.4.	Yes	
§ 6.6.4	**Inspection Criteria**	Nondestructive examination methods, limitations on defects, the qualifications of the authorized inspector, and the personnel performing the examination shall meet the requirements of ASME B 31.3, Process Piping, Sections 340 and 344. Exception: Substitution of in-process examination for radiography or ultrasonics as permitted in ASME B 31.3, Paragraph 341.4.1, shall be prohibited.	Yes	
§ 6.6.5	**Record Retention**	Test records and written procedures required when conducting nondestructive examinations shall be maintained for the life of the piping system or until such time as a reexamination is conducted. Records and certifications pertaining to materials, components, and heat treatment as required by ASME B 31.3, Process Piping, subparagraphs 341.4.1(c) and 341.4.3(d) and Section 346, shall be maintained for the life of the system.	Yes	

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 6.7	**Purging of Piping Systems**			
§ 6.7.1		Systems shall be purged of air or gas in a safe manner	Yes	
§ 6.7.2		Blow-down and purge connections shall be provided to facilitate purging of all process and flammable gas piping.	Yes	
§ 6.8	**Safety and Relief Devices**			
§ 6.8.1		Pressure-relieving safety devices shall be arranged so that the possibility of damage to piping or appurtenances is reduced to a minimum. The means for adjusting relief valve set pressure shall be sealed.	Yes	
§ 6.8.2		A thermal expansion relief valve shall be installed as required to prevent overpressure in any section of a liquid or cold vapor pipeline that can be isolated by valves.	Yes	
§ 6.8.2.1		A thermal expansion relief valve shall be set to discharge at or below the design pressure of the line it protects.	Yes	
§ 6.8.2.2		Discharge from such valves shall be directed to minimize hazard to personnel and other equipment	Yes	
§ 6.9	**Corrosion control**			
§ 6.9.1		Underground and submerged piping shall be protected and maintained in accordance with the principles of NACE RP 0169, Control of External Corrosion of Underground or Submerged Metallic Piping Systems.	No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 6.9.2		Austenitic stainless steels and aluminum alloys shall be protected to minimize corrosion and pitting from corrosive atmospheric and industrial substances during storage, construction, fabrication, testing, and service. Tapes or other packaging materials that are corrosive to the pipe or piping components shall not be used. Where insulation materials can cause corrosion of aluminum or stainless steels, inhibitors or waterproof barriers shall be utilized.	Yes	
Chapter 7	**Instrumentation and Electrical Devices**			
§ 7.1	Liquid Level Gauging			
§ 7.1.1	LNG Containers			
§ 7.1.1.1		Two independent liquid level gauging devices to be provided on LNG containers - Density variations shall be considered.	Yes, for topsides	IGC code and classification rules are applied to storage tanks.
§ 7.1.1.2		Two independent high-liquid level alarms, to be provided, may be part of liquid level gauging devices.	Yes, for topsides	IGC code and classification rules are applied to storage tanks.
§ 7.1.1.3		High-liquid-level flow cutoff device separated from all gauges to be provided on LNG containers	Yes, for topsides	IGC code and classification rules are applied to storage tanks.
§ 7.1.2	Tanks for Refrigerants or flammable Process Fluids		Yes, for topsides	IGC code and classification rules are applied to storage tanks.
§ 7.2	Pressure Gauge		Yes, for topsides	IGC code and classification rules are applied to storage tanks.

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 7.3	Vacuum Gauge		Yes, for topsides	IGC code and classification rules are applied to storage tanks.
§ 7.4	Temperature Indicators		Yes, for topsides	IGC code and classification rules are applied to storage tanks.
§ 7.4.1	Vaporizers	Vaporizers to be provided with indicators to monitor inlet and outlet temperatures of LNG, vaporized gas and heating-medium fluids	Yes	
§ 7.4.2	Heated Foundations of Cryogenic Containers and Equipment		No	Facility has no heated foundations.
§ 7.5	Emergency shutdown	Instrumentation to be designed as fail-safe type in case of loss of power or instrument air	Yes	
§ 7.6	Electrical Equipment			
§ 7.6.1		Electrical Equipment and Wiring to be specified by and installed in accordance with NFPA 70, National Electrical Code or CSA C22.1, Canadian Electrical Code for hazardous locations	No, the FSRU will comply with the IEC	
§ 7.6.2		Extent of classified areas around hazardous sources and specification of fixed electrical equipment and wiring for that zone	No, IP15 is the Hazardous Area Classification Code that applies in conjunction with IEC60079 is the selected standard to apply	
§ 7.6.3		Interface between flammable fluid system and electrical conduit/wiring to be sealed or isolated to prevent passage of fluid to any portion of electrical equipment	Yes	
§ 7.6.3.1		Design of seals quoted above	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 7.6.3.2		Concept of primary / additional seals or barriers	Yes	
§ 7.6.3.3		Design of primary / additional seals or barriers to withstand to service conditions or potential conditions	Yes	
§ 7.6.3.4		Venting requirement on the space separating primary and secondary seals	Yes	
§ 7.6.3.5		Seals as per § 7.6.3, 7.6.4 and 7.6.5 not to be used to meet sealing requirements of NEC	No, FSRU design will comply with IEC	
§ 7.6.4		Requirements for monitoring flammable liquid leakage from primary seals	Yes	
§ 7.6.5		Venting of conduit systems in a safe location	Yes	
§ 7.7	Electrical Grounding and Bonding			
§ 7.7.1	General	Electrical grounding and bounding to be provided	Yes	
§ 7.7.2	Bonding		Yes	
§ 7.7.3	Stray or Impressed Currents		Yes	
§ 7.7.4	Lightning Protection	Lightning protection not required on LNG storage containers	Yes	
Chapter 8	**Transfer of LNG and Refrigerants**			
§ 8.1	General			
§ 8.1.1		Scope of the chapter	Information	
§ 8.1.2		Application of NFPA59A to transfer facilities	As evaluated through this review table	
§ 8.2	Piping Systems			
§ 8.2.1		Isolation valve requirements at each extremity of LNG transfer system - Mitigation of hydraulic shock	Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 8.2.2		Pre-cooling capability for piping system used for periodic transfer of cold fluid	Yes	
§ 8.2.3		Check valve on transfer systems	Yes	
§ 8.3	Pump and Compressor Control			
§ 8.3.1		Local + remote shutdown station to be provided for the shutdown of transfer pump or compressor drive, located at least 25 ft from the equipment - Additional shutdown station to be provided at loading / unloading area if any	No	Alternate safety measures will be proposed as compensation (physical barrier. . .)
§ 8.3.2		Signal lights indicating status of transfer pumps or compressors	Yes	
§ 8.4	Marine Shipping and Receiving			
§ 8.4.1		Design of the berthing area to be in accordance with requirements of authorities having jurisdiction		To be determined - US Coast Guard rules for safety will be applied.
§ 8.4.2		Other cargo transfer or ship bunkering not allowed within 30 m distance from the LNG transfer connection points	Yes	
§ 8.4.3		Location of pipelines with respect to vehicle traffic and other possible causes of physical damage, marine traffic	No	Not applicable as FSRU is not a pier
§ 8.4.4		Isolation valving and bleed connections at the loading / unloading manifold on liquid and vapor return lines - Remote control station of the liquid isolation valves to be located at least 15 m from the manifold area - Safety requirements around valve actuation design	Yes	
§ 8.4.5		Additional isolation valves on shore near to the approach to the pier or dock	No	US Coast Guard and classification rules to be applied.

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 8.4.6		Pipelines used for liquid unloading to be provided with a check valve close to manifold isolation valve	No	US Coast Guard and classification rules to be applied.
§ 8.4.7		Vapor return line to be connected to vessel's return connections	Yes	
§ 8.5	Tank Vehicle and Tank Car Loading and Unloading Facilities		No	
§ 8.6	Pipeline Shipping and Receiving			
§ 8.6.1		Isolation valves between transfer systems and pipeline systems	Yes	
§ 8.6.2		Pressure or temperature limitations	Yes	
§ 8.6.3		"No smoking" signs posted at loading / unloading areas	Yes	
§ 8.6.4		Marking of loading arms, hoses and manifolds where multiple products are loaded or unloaded	Yes	Should not occur on FSRU
§ 8.6.5		Bleed and vent connections on loading arm and hoses for drainage and depressurization prior to disconnection	Yes	
§ 8.6.6		Venting to safe location during transfer	No	All vents are led into the vapor header and recovered
§ 8.7	Hoses and arms			
§ 8.7.1		Pressure and temperature design conditions	Yes	
§ 8.7.2		Flexible metallic hose or pipe and swivel connections to be used for T° below -51°C	Yes	
§ 8.7.3		Alarms for indicating arms approaching their extension envelope	Yes	
§ 8.7.4		Provisions for arm supports	Yes	
§ 8.7.5		Annual test and visual inspection before use	Yes	No applicable hoses on FSRU

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 8.8	Communications and Lighting			
§ 8.8.1		Means of communication between operators involved in loading / unloading operations	Yes	
§ 8.8.2		Lighting at transfer area	Yes	
Chapter 9	**Fire Protection, Safety and Security**			
§ 9.1	General			
§ 9.1.1		Scope of the chapter	Information	
§ 9.1.2		Fire Protection to be determined by an evaluation based on sound fire protection engineering principles	Yes, for topsides only	IGC code and classification rules are used for hull areas.
§ 9.1.3		Detailed fire protection provisions not included	Information	
§ 9.2	Emergency Shutdown Systems			
§ 9.2.1		Need for emergency shutdown system	Yes	
§ 9.2.2		Exception to equipment shutdown	Yes	
§ 9.2.3		ESD system of a fail-safe design or with components located 15 m from the equipment to be controlled and operable during 10 min when engulfed in fire	Yes	
§ 9.2.4		Distribution of operating instructions for emergency control devices all over the FSRU	Yes	
§ 9.2.5		Manual/automatic initiation of ESD systems	Yes	
§ 9.3	Fire and Leak Control			
§ 9.3.1		Monitoring as required per § 9.1.2 of areas that have potential for flammable gas concentrations, LNG or flammable refrigerant spill or fire	Yes	

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 9.3.2		Alarming to be activated on low-temperature sensors or flammable gas detectors at plant site and CCR - Audible and visual alarm at 25% LFL	Yes	
§ 9.3.3		Alarming to be activated fire detectors at plant site and CCR - Initiation of ESD as required per § 9.1.2	Yes	
§ 9.3.4		Fire, gas and spill detection systems to be designed against NFPA 72 and NFPA 1221	No	IGC code and ABS Rules will take precedence
§ 9.4	Fire Protection Water Systems			
§ 9.4.1		Requirement for a water supply and distribution system for protection of exposures, cooling containers, equipment and piping, controlling leaks and spills	As evaluated per § 9.1.2	Water protection is provided as per IGC code on the cargo tank top where required; exposure protection applies where deemed necessary as per § 9.1.2
§ 9.4.2		Design of fire water supply based on maximum single incident + allowance of 1000 gpm for hand hose streams	Yes	
§ 9.5	Fire Extinguishing and Other Fire Control Equipment			
§ 9.5.1		Fire extinguishers for gas fires to be provided at strategic locations as determined per § 9.1.2 - NFPA 10 is to apply	Yes, for topsides only	IGC code and classification rules are used for hull areas.
§ 9.5.2		Fire trucks	No	
§ 9.5.3		Automotive vehicles with portable fire extinguisher	No	
§ 9.6	Maintenance of fire protection equipment	Requirement for having a maintenance program for all plant fire protection equipment	Yes	
§ 9.7	Personnel Safety			

NFPA59A	*TITLE*	*SUBJECT*	*APPLICABILITY*	*COMMENT*
§ 9.7.1		Requirement for protective clothing against the effects of exposure to LNG to be readily accessible at the facility	Yes	
§ 9.7.2		Requirement of necessary protective closing and equipment for fire fighting team - NFPA 600 is to apply	No, it is as per IGC code and Company practice	
§ 9.7.3		Need for confined space entry procedure	Yes	
§ 9.7.4		At least 3 portable flammable gas indicators to be readily available	Yes	
§ 9.8	Security		Not applicable to offshore facilities - Specific approach applies here	
§ 9.9	Other Operations			
§ 9.9.1		Manual emergency depressurizing means to be provided where necessary. Venting to atmosphere is acceptable as far as it minimizes exposure to personnel or equipment	Yes	
§ 9.9.2		Preparation of detailed procedure for taking a LNG container out of service	Yes	
Chapter 10	**Alternate Requirements for Stationary Applications Using ASME Containers**		No, LNG cargo tanks do not follow ASME rules but IGC code	
Chapter 11	**Operating, Maintenance and Personnel Training**			The subjects of each subsection has not been developed at this stage as it mostly refers to general and usual organizational measures
§ 11.1	General		Yes	
§ 11.2	Basic Requirements		Yes	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 11.3	Documentation of Operating Procedures		Yes	
§ 11.3.1	Manual of Operating Procedures		Yes	
§ 11.3.2	Manual contents			
§ 11.3.3	Emergency Procedures		Yes except (2) b. and (3) that are not applicable to Broadwater offshore location	
§ 11.3.3.1		Method of advising appropriate local offices of emergency procedures	Yes	
§ 11.3.4	Monitoring Operation			
§ 11.3.4.1			Yes	
§ 11.3.4.2			Not applicable to floaters	
§ 11.3.5	Cool down Procedures			
§ 11.3.5.1			Yes	
§ 11.3.5.2			Yes	
§ 11.3.6	Purging		Yes	
§ 11.3.6.1	General		Yes	
§ 11.3.6.2	Container Purging Procedures		Yes	
§ 11.3.6.3	Purging of Piping Systems		Yes	
§ 11.3.7	Product Transfer		Yes	
§ 11.3.8	Record Keeping		Yes	
§ 11.4	Marine Shipping and Receiving			
§ 11.4.1	General Cargo		No	
§ 11.4.2	Vehicle traffic		No	
§ 11.4.3	Cargo transfer		Yes	
§ 11.4.4	Tank Vehicle and Tank Car Loading and Unloading Facilities		No	

NFPA59A	TITLE	SUBJECT	APPLICABILITY	COMMENT
§ 11.4.5	Loading and Unloading Operations			
§ 11.4.5.1	General			
§ 11.4.5.2	Tank Car or Tank Vehicle		No	
§ 11.4.6	Communication and Lighting		Yes	
§ 11.5	Maintenance			
§ 11.5.1	General		Yes	
§ 11.5.2	Maintenance Manual		Yes	
§ 11.5.3	Site Housekeeping			
§ 11.5.4	Repairs			
§ 11.5.5	Control Systems, Inspection and Testing		Yes, but the code listed in c) may be superseded by other codes identified as being applicable	Applicable codes for offshore installations as per US Coast Guard and classification society are used as control, inspection, and testing basis
§ 11.5.6	Corrosion Control		Yes	
§ 11.5.7	Records		Yes	
§ 11.6	Training			

13.15 SOILS AND SEISMICITY

The issues covered by Section 15 are addressed in Resource Reports 6 and 7.

These reports include details of the geotechnical field investigations conducted in the spring of 2005 (Resource Report 7) and other geological information.

13.16 YOKE MOORING SYSTEM

13.16.1 Design Rules & Regulations

The Yoke Mooring System is approved as part of the classification process for the FSRU facility in accordance with Class Rules.

The four major components (tower, turntable structure, yoke, and MMS) each have systems that utilize system-specific design codes and standards.

The design of electrical systems, including hazardous area identifications, normal and emergency lighting, navigation aids lighting, and power distribution, are in accordance with codes and regulations from API, IEC, IP, and USCG.

The design of mechanical equipment, including winches and lifting equipment is in accordance with codes and regulations from API and the ASME.

The design of piping components including all swivels, HP gas lines, ESD valves, and risers from the sea floor are in accordance with codes and regulations from API and ASME.

The design of safety systems including monitoring, pressure relief systems, fire detection and suppression, lifesaving, and occupational safety, are in accordance with codes and regulations from ABS, API, IMO, USCG and the NFPA.

The design of structural components is in accordance with codes and regulations from API and the American Welding Society (AWS).

Compliance during design and construction of the mooring system is overseen by ABS.

A list of all applicable codes can be found in the appendices, Section 13.16.

13.16.2 Yoke Mooring System Technical Description

The Broadwater FSRU is connected by means of a soft YMS to a jacket, which is piled to the seabed. The jacket or tower is a tubular steel space frame structure of square horizontal cross-section with legs in each of its four corners. The jacket also supports the gas pipeline riser. At the base of the jacket there is a square mud mat, the corners of which are connected to the jacket legs. At each of the four mud mat corners there is a pile guide through which skirt piles are driven. A central column or 'king post' is located at the top of the jacket onto which the turntable is mounted. The turntable structure or 'topsides module' houses the swivel stack, and is connected by means of a slewing bearing to the top of the king post. This allows the FSRU together with the mooring yoke to weathervane around the piled jacket.

The mooring yoke consists of a rigid triangular tubular structure which is connected at the jacket end by a roll and pitch articulation to the turntable, and at the FSRU end by two mooring legs, to the MSS mounted on the FSRU's bow.

The mooring yoke, which is partially filled with water ballast, is suspended from the two mooring legs that hang vertically when the system is in equilibrium with the facility at rest. When the facility moves as a result of environmental effects, the ballast weight in the mooring yoke is raised and thus creates a restoring force which acts to bring the FSRU back to the equilibrium position. Any movements of the FSRU (roll, pitch, yaw, surge, heave, sway) with respect to the jacket are allowed for by articulations at each end of the mooring legs, at the mooring yoke/turntable connection, and by the main slewing bearing. The mooring system configuration is such that the mooring yoke is suspended above the normal water level.

The transfer of send-out gas from the FSRU is achieved through a series of flexible jumpers which are suspended between the MSS and turntable structure. The jumpers are flexible pipes of a HP design that transport the gas to the gas swivel on the mooring tower. The gas then passes through the swivel assembly and into the pipeline riser, located within (and attached to) the mooring tower structure. Gas travels down the riser to the remainder of the pipeline system. Although these components differ from the fixed pipeline system used with land-based LNG terminals, the components of the system perform the same transportation function, while allowing the FSRU to rotate around the fixed mooring tower. The mooring tower provides support to the pipeline riser and is configured to allow pipeline maintenance activities to occur (e.g., pig launching facilities are provided on the mooring tower). The interconnecting pipeline and the mooring tower are therefore part of an integrated system.

In addition to the jumpers, there are also a series of umbilicals (cables) which provide utilities to the YMS. This would include electrical power, compressed air and water, and control signals.

General Arrangement drawings of the complete soft YMS, as well as additional information can be found in the appendices, Section 13.16.

The primary Yoke Mooring System design will safely accommodate the most severe weather that can credible occur in the area including hurricanes and Northeasters. The redundancy within the mooring system and the reduced environmental loadings resulting from the weathervaning FSRU reduce the risk of a mooring failure to as low as reasonably practicable. For this reason, a secondary mooring system has not been incorporated within the design. Additional mitigation measures may be possible by using the azimuth thrusters to reduce the load on the mooring system during severe storm conditions and possibly the use of these thrusters to steer the FSRU or arrest progress in the unlikely event of a mooring failure. The only credible secondary mooring system would be the provision of anchors on the FSRU but the effectiveness and risks associated with this solution would need careful analysis particularly in light of the low risk of mooring failure.

The company that will be contracted to design and construct the YMS has not yet been selected, however a similar design specified in this section has been used successfully in 8 other worldwide locations, mainly in South East Asia and West Africa. A West African example of the same design has been in operation for 3 years and moors a Floating Production, Storage and Offloading unit (FPSO). This technology is accepted and proven design for shallow water mooring installations.

Loadings, both static and dynamic, were considered in the design of all the components of the Yoke Mooring System (YMS).

The SBM Broadwater mooring analysis did not include any loading conditions with an LNG carrier moored alongside the FSRU. The loading conditions analyzed were with the FSRU moored to the YMS by itself loaded to a draft of 12.3 meters. A detailed side-by-side analysis was not performed because the mooring loads are proportional to the wave height. The side-by-side condition is an operating condition and has a specified Hs of 2.0m, and the survivability condition has a specified Hs of 7.0m. Based on this, it was determined that the survivability mooring loads would greatly exceed those of the side-by-side operating condition.

To check the design and strength requirements for a mooring system (including a YMS), the extreme weather event dictated by codes for the system is analyzed. In the Broadwater case, however, the specified weather conditions as set forth in Appendix 13.6 "YMS design basis, metocoean and geotechnical information" were used and is the governing case for the mooring system design. Further information on the FSRU/YMS survivability criteria is set forth in Resource Report 11, Section 11.3.2.1. The FSRU in a damaged condition was not analyzed, as the mooring loads will not differ with a change in FSRU stability unless the stability of the FSRU is completely compromised.

APPENDICES TO RESOURCE REPORT 13.16

Yoke Mooring System (YMS) Appendix
FSRU topsides motions & accelerations/312383-SBM-CAL-100
Tower soft YMS layout sheet 1, equipment arrangement/312383-SBM-DWG-000
Tower soft YMS layout sheet 2, equipment arrangement/312383-SBM-DWG-001
Tower soft YMS general arrangement/312383-SBM-DWG-002
Tower soft YMS swivel stack, general arrangement/312383-SBM-DWG-500
Tower soft YMS hazardous area classification and detection sheet 1/312383-SBM-DWG-701
Tower soft YMS hazardous area classification and detection sheet 2/312383-SBM-DWG-702
Tower soft YMS egress & safety equipment locations sheet 1/312383-SBM-DWG-703
Tower soft YMS egress & safety equipment locations sheet 2/312383-SBM-DWG-704
Preliminary installation philosophy/312383-SBM-INF-001
Tower soft yoke process-PFD/312383-SBM-PFS-400
Tower soft yoke utility-PFD/312383-SBM-PFS-401
Tower soft yoke E & I electrical power distribution/312383-SBM-SLD-200
Noble Denton Guidelines
YMS design basis, Metocoean and geotechnical information

13.17 MOORING AND LOADING FACILITIES

13.17.1 General

The interface and interaction between the LNG carrier and FSRU is in accordance with common marine practice. LNG carriers approach, berth and moor to the FSRU in a side-by-side configuration whereby approach and berthing is assisted by pilot and tugs.

The LNG carrier is secured to the FSRU by dedicated mooring wires that are configured and secured using fairleads and quick release hooks that are permanently fitted to the FSRU. To accommodate the relative motions of the FSRU and LNG carrier while moored and to prevent contact, floating soft pneumatic fenders are used to separate the hulls.

Transfer (loading) of the cargo from the carrier to the FSRU is via hydraulically controlled loading arms fixed to the FSRU and connected to the cargo manifold of the carrier. There are both liquid and vapor connections.

Communication between the FSRU and the LNG carrier is made by an optical fiber link system which incorporates ESD, mooring tension signals and telephone systems.

Full details and drawings of the mooring and loading system and its components are set forth in the appendices, Section 13.17.

APPENDICES TO RESOURCE REPORT 13.17

Mooring and LNG Loading Facilities Appendix

LNGC-FSRU interface side view and plan view/312383-SHI-DWG-000.01

LNGC-FSRU interface side view and plan view, section view/312383-SHI-DWG-000.02

LNGC-FSRU interface side view and plan view, plan view/312383-SHI-DWG-000.03

LNGC-FSRU interface side view and plan view, section view/312383-SHI-DWG-000.04

LNGC-FSRU interface overview drawings (sections and details, FSRU, ballast condition)/312383-SHI-DWG-001.01

LNGC-FSRU interface overview drawings (sections and details, FSRU, ballast condition)/312383-SHI-DWG-001.02

LNGC-FSRU interface overview drawings (sections and details, FSRU, loaded condition)/312383-SHI-DWG-001.03

LNGC-FSRU interface overview drawings (sections and details, FSRU, loaded condition)/312383-SHI-DWG-001.04

Loading arms elevation/312383-SHI-DWG-407.01

Section view loading arms elevation/312383-SHI-DWG-407.02

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-003-01

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-003-02

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-003-03

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-003-04

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-003-05

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-003-06

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-001-01

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-001-02

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-001-03

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-001-04

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-001-05

FSRU-LNGC PLAN VIEW 312383-WSN-DWG-001-06

13.18 ACCOMMODATION AREA

13.18.1 General

The FSRU has 30 permanent crew members and 30 temporary crew members (commissioning, training, shutdown, and additional maintenance crew). An accommodation area is provided, which will be aft of the LNG containment area. The accommodation area will be designated as the main TR.

Accommodation spaces, including public space, private space, office space, catering space, sanitary space and machinery space, are provided in accordance with applicable Class Rules and ILO.

The accommodation area is further described in the appendices, Section 13.18, and Technical Specifications for the accommodation area are set forth in Specification No. 312383-SHI-SP-901, in appendix Section 13.18.

APPENDICES TO RESOURCE REPORT 13.18

Accommodation Appendix
Cabin Plan upper deck/312383-SHI-DWG-405.01
Cabin Plan A deck/312383-SHI-DWG-405.02
Cabin Plan B deck/312383-SHI-DWG-405.0`3
Cabin Plan C deck/312383-SHI-DWG-405.04
Cabin Plan D deck/312383-SHI-DWG-405.05
Cabin Plan E deck/312383-SHI-DWG-405.06
Cabin Plan /312383-SHI-DWG-405.07
Cabin Plan /312383-SHI-DWG-405.08
Specifications for accommodation/312383-SHI-SP-901